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CONCRETE

ROADS AND PAVEMENTS

(Revised Edition)

By

E. S. HANSON

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Author "Cement Pipe and Tile," etc.

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PREFACE.

The first edition of this book came out just a year ago and was so well received that the first printing was sold before all the books came from the bindery. A second printing, with a few slight changes and corrections, was then put on the press and has been sold out some time ago. Hence the writer has been led to believe that there is a large demand for information on the subject of concrete roads and pavements, and he has therefore derived considerable enjoyment from the preparation of the present complete revision of the book, in the hope that by this means he may be able to add a small part to the betterment of this rapidly developing branch of the concrete industry.

The book has been expanded from thirteen chapters in the original volume to twenty chapters in this revision, and from 227 pages to 338 pages. Entire new subjects have been introduced in this volume, such as Chapter XIX on the promotion of concrete roadways.

Then, too, some topics which were merely given a paragraph in the original edition are now expanded into chapters. In each case it may be said, also, that the work has been brought completely down to date and that such advances in practice as have been developed during the past year are included in this volume.

The book is, in large part, frankly a compilation, and the effort has been to collect into convenient handbook size everything of value which is so far known on the subject.

E. S. HANSON.

Chicago, August 1, 1914.

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Concrete Roads and Pavements

CHAPTER I.

Concrete as a Road Material.

It is assumed at the outset that the reader is a person sufficiently well informed to recognize the value of good roads and pavements, so that it will not be necessary here to take up any arguments in behalf of the subject as a whole. Such work is much needed, to be sure; but the one who takes up this book will already be a convert to this good roads movement, and will look to these pages, not for enthusiasm in the cause—which he already possesses—but for information and instruction regarding a type of roadway which has made rapid advancement within the past few years.

Without further preliminaries, therefore, let us consider the essentials of a good roadway, so that we may see what the standards are by which a road must be measured. We shall then be in a position to apply the test to concrete roads and pavements and see how they measure up to the standard.

The most scientific discussion of the qualities of a good roadway which the writer has seen is that of Mr. Geo. W. Tillson, consulting engineer to the President of the Borough of Brooklyn, City of New York. This is given in the second edition of Mr. Tillson's volume entitled "Street Pavements and Paving Materials." Supposing the perfect pavement to have a value of 100, Mr. Tillson assigns various percentages to the different qualities, the list being as follows:

Cheapness	14
Durability	21
Ease of cleaning	15
Resistance to traffic	15
Non-slipperiness	7
Ease of maintenance	10
Favorableness to travel	15
Sanitariness	13
	100

This table was prepared primarily with city pavements in mind, and would perhaps be subject to some variation for country roads. Nevertheless, the writer is inclined to believe that it is just and fair, though he would possibly feel like giving a somewhat higher value to the item of maintenance.

The application of this table of values to concrete roadways will show them to have decided advantages on every count.

Cheapness. This relates primarily to first cost, leaving out of consideration for the time being any thought whatever of the ultimate, long-time, or real cost. That is, can a given community pay the initial cost of concrete without unduly drawing upon its present resources or too heavily mortgaging the future?

In answering this question, city pavements and country roads will have to be considered separately, inasmuch as in practically all localities the custom has been to accord the two an entirely different treatment, giving the city street a durable, well built pavement, while the country road has been content with almost any makeshift it could get. This is a condition which we believe will continue but a few years longer, except in very sparsely settled districts where the construction of permanent roads is out of the question; but so long as it remains it must be considered in any discussion of this kind. The automobile is accused of many things in connection with street and road problems; but it can at least be credited with this, that it is serving to wipe out the line of demarcation between the city and the country, so that the builder of good roads cannot longer feel that his work is done when he has worked out to the city limits. The time is coming when roadways will be considered very largely as a unit, irrespective of municipal boundaries; but until that time they will have to be treated separately.

Taking up first, then, the cost of city pavements, a few comparative figures will serve to show that concrete is not high in first cost. We give cost data on these pavements in several different places in this volume, but the large table of work done in 1913 will perhaps be sufficiently comprehensive for purposes of comparison, and the figures are more recent than many others given.

In this table, which was compiled by *The Cement Era,* there are given cost figures for 97 cities; and while these figures were compiled from a number of different statements, representing, perhaps, widely divergent ideas as to what should be included in a cost statement, they are fairly representative, and it is of interest to note that they average a cost of $1.41 per square yard. Figures compiled by *Engineering and Contracting* for 157 cities are practically the same, or $1.38 per square yard. While some of these statements include grading, many of them do not, as this is highly variable, the cost depending on the nature of the soil and the contour of the ground. They probably in most cases do not include also the item of engineering supervision and administrative expenses. Some of the work was probably done, too, when cement was very low in price, so that a cost of $1.50 per square yard is perhaps as close a total average figure as can be given.

And yet, taking all these things into consideration, the man who has had experience either in buying or building city pavements will know that this is as low a price as will buy any kind of a pavement acceptable to the general public. In fact, it is below the average price of any other material which any enterprising city would think of using.

It is interesting to compare the price of concrete pavement with the price of other classes of pavements as compiled by *Engineering and Contracting* in the same issue above referred to. In 283 cities reported as laying brick pavement, the average price was $1.97; for stone block in 66 cities, $3.00; for wood block in 72 cities, $4.21, and for asphalt in 107 cities, $1.89. These figures are all for work laid in 1913.

These figures are also exclusive of grading in a large number of cases and are also subject to an additional charge for overhead expense, as in the case of concrete.

The situation regarding the use of concrete for country roads is entirely different. The first cost is naturally much higher than some of the forms of construction which have been considered good enough in the past. Concrete cannot hope to compete with ordinary dirt or gravel roads in first cost; but when its advantages of long life and low maintenance expense become fully established it will replace these, at least on most of the main highways of this country, and even on less important roads where the population and wealth are sufficient to make it possible.

It is interesting to note, as this book is being revised, that state and county highway officials seem to be making very rapid progress in their experiments with concrete highways and are using concrete even more than it is being used in cities for pavements. They seem to have fallen in with the idea of concrete roads and have been willing to invest the money required for them even more rapidly than was anticipated when the first edition of this book was prepared. The reason of this is probably that while cities have had various other kinds of hard pavements which they have been using, highways have heretofore been built largely either of dirt or macadam, and these have proven themselves entirely unsuited for present traffic.

The eighth annual report of the Commissioner of Highways for the State of Maine, for the year 1912, contains a summary of the work done, in which is included six contracts on concrete roads totaling 21,128 square yards and averaging $1.52 a square yard. This roadway all has bituminous top coating. This figure includes all expenses, such as grading, manholes, drains, engineering and superintendence. Even at this, it is scarcely a representative figure, as it includes 1,000 square yards at South Portland, which ran up to a price of $2.10 per square yard, owing to the fact that a large amount of rock base had to be put in. Leaving out this contract the five remaining contracts show a total of 20,128 square yards put in complete at an average figure of $1.40 per square yard.

Durability. While concrete has not been used as a road-making material long enough to determine its life in this use from actual experience, very fair inferences may be drawn from the general behavior of concrete under wear, as well as from the behavior of such pavements as have been in use for a considerable length of time. In taking account of this latter item, however, due allowance must be made for the fact that the first concrete roads, like the first concrete buildings, were not constructed in accordance with present-day practice, and were far from reaching the degree of perfection which is now attained.

There are two elements to be considered in determining the suitability of a material for a roadway—its wear under the elements and its resistance to traffic. That concrete can qualify under the first of these requires no argument. It has proven itself able to withstand any attack of atmospheric conditions, conditions of soil, fire, etc., at least as well as the best of natural stone, as is amply shown by the large number of miscellaneous structures, under all kinds of conditions, which it has to its credit.

While one may point for confirmation of his assertion of the durability of concrete roads to a large number of such roads which are standing up most successfully under traffic, perhaps one of the most conclusive proofs of the value of concrete for this purpose is to be found in the comparative tests which have been made at Detroit with a device known as a paving determinator. This device was designed and built by Mr. John C. McCabe, boiler inspector of Detroit, for the Department of Public Works, with the idea of subjecting sample pavements to wear as closely approximating actual conditions as possible. Eight sections of as many different kinds of pavement were first tested by this machine, a concrete section built under the Wayne County specifications giving by far the best wear. Full details of the tests made by this machine are given in Chapter XVIII.

As long as our roads were subjected entirely to ironbound traffic the macadam roads served very well indeed. This type of road depends for its integrity upon the binding power of the stone dust of which the surface is composed. The horses' hoofs and the tires of the wheels produced just enough fine material to replace that which was blown away.

With the advent of the motor vehicle, however, entirely different conditions arose. With such vehicles the power is applied entirely to the rear wheels and these rubber tired wheels in turn exert a tremendous shearing and tearing force on the surface of the road, displacing this surface and producing no fine material to replace it.

Many binding materials have been tried with which it was hoped to hold the stones in the road more firmly in position, but either due to lack of strength or due to the fact that they disintegrate under climatic conditions and become weak, little success was attained in reducing this maintenance cost until the advent of the concrete highway. Road engineers throughout the country are turning to the concrete road as a solution of this maintenance cost problem and the very small amount of money needed to keep such a pavement in repair justifies them in so doing.

The attempt to limit the traffic to fit the road, rather than building the road to fit the traffic, is only a temporary expedient and cannot be adhered to for any great length of time. If vehicles can be safely and economically built for the transportation of large loads over the highways and time and money can be saved by their use the public will not long tolerate a prohibition upon their use and the roads will have to be built to accommodate them.

In order that a road may not disintegrate under the severest traffic a binding material must be used in its construction which will remain permanent in any temperature and which will not be affected by climatic conditions, a binding material which will hold the stones so firmly in place that they cannot be dislodged by either light or heavy horse-drawn traffic, nor by the fastest moving automobile, nor by the immense motor truck.

Portland cement is the only binder known which will answer these requirements. It is the only binder which not only does not weaken, but actually grows stronger with age. The concrete road offers to those engaged in transporting heavy loads an ideal pavement, a pavement which will not become soft in summer nor brittle in winter; a pavement which is not slippery in wet weather, nor dusty in dry; a pavement which is suitable for both horse-drawn and motor vehicles and which, owing to its slight crown and even surface, offers a maximum width of road available for traffic, as well as a minimum of tractive resistance.

In Scribner's Magazine for February, 1914, the leading article is devoted to the subject "The Motor and the Highway," and it is interesting to note what Mr. Rollin W. Hutchinson, Jr., says in this article:

"In 1913 about 36,000 motor trucks were made in this country, or 6,000 more than the entire history of the industry had up to then recorded. This history indicates that the number of trucks going into service may be doubled each year until highway commerce becomes completely motorized."

And further, in referring to the question of highways, he says: "No motor truck—even if it were practicable to build it to carry a weight of twenty tons on each axle—could do the slightest damage to a highway of concrete. Such highways can be constructed at but little greater initial cost than the now common, superficial, highly expensive to maintain macadam roads."

In some instances farming communities when first approached upon the subject of concrete roads, object to what they regard as very high cost for construction; but when they come to look at a road as an investment, which is the proper way to consider highway improvement, they find that a $12,000 a mile concrete road is far cheaper than a macadam road costing $6,000 per mile. This is due to the vast difference in maintenance costs. In some cases concrete roads in constant use for a period of four or five years have cost practically nothing for maintenance, whereas macadam roads in this day, if subject to automobile traffic, represent an annual outlay of from $600 to over $1,000 per mile per year for repairs. The record in five eastern states for 1912 was in excess of $800. New York alone spent over $1,000. Now assuming that a macadam road could be built for $6,000 a mile and that annual maintenance would be only $300 per mile, this $300 would represent 5 per cent interest on $6,000, which would really make the road investment $12,000 per mile, or about the cost of an indestructible concrete road.

Where the preponderance of traffic is motor driven the concrete road represents the very maximum of economy. Ordinary types will not stand the stress of motor-driven traffic. The rapidly revolving wheels disperse the rock dust or binding material of macadam roads and the stones are ripped out and cast aside, whereas the rubber tires have no effect upon roads built of concrete. Even a torrential rain will wash the best type of macadam roads into ruts and gulleys, and while it may wash under or over a concrete road, it can never pass through it, and hence these roads are always in first-class condition.

Comparing concrete and macadam pavements, Mr. Logan Waller Page, director of the Office of Public Roads, made the following statement before a meeting of the Association of American Portland Cement Manufacturers in 1912:

"In the matter of sustaining normal loads the capacity of concrete pavements as compared with the capacity of ordinary macadam or bituminous macadam surfaces must be superior. Numerical data or experimental evidence on this subject is as yet meager. It is not difficult, however, to draw certain definite conclusions when we consider the nature of the materials involved. It is well known that macadam roads have rutted under heavy loads. For ruts to develop rapidly it is quite evident that some shearing of the macadam surface occurs. Of course, rutting also takes place, because of wear and lateral displacement of stone. The capacity of concrete pavements to resist shear is relatively much greater, and we may perhaps note this as the first point of superiority of concrete over macadam pavements for sustaining normal loads.

"It is common practice to assume, in designing concrete bridge floors, that normal pressures over an area are transmitted through the slab in lines of pressure whose boundary surface is conical, with elements at an angle of 45 degrees or more with the horizontal. It scarcely needs demonstration that the same assumption cannot hold for macadam slabs, *i. e.,* normal pressure cannot be transmitted by a macadam slab over as large an area of the sub-grade, and this, it is reasonable to record, is a second advantage of concrete over macadam construction.

"From the comparisons made above between Portland cement concrete and plain macadam or bituminous macadam, it is evident that we may be practically assured that the Portland cement concrete road is far better able to meet the changing traffic conditions than either of the other materials. From our knowledge of the strength of Portland cement concrete, we can design a road surface of this material to meet practically any traffic requirement."

"One of the reasons why we gave up the building of macadam roads in Wayne county," says Edward N. Hines of Detroit, "was because of the inability of macadam to stand up under automobile traffic. At slow speed the macadam road is not greatly injured by automobiles, but at high speed the macadam is stripped of the binding material holding larger stone particles of the macadam road together. One advantage of the concrete road over the macadam road is that concrete is not dusty. The dust which an automobile raises on a macadam road, besides being a menace to health, is good stone dust that is badly needed on the road and is not needed at all in the fields where it usually settles. No oil or special preparation is necessary to keep the dust down on the concrete road. The drier the weather the cleaner the road. The only dust that is to be found on a concrete road comes from mud that has been tracked on the concrete."

The City Club of Milwaukee in June, 1914, made a careful investigation of concrete roads in Milwaukee county, from the standpoint of both durability and economy. This club is organized "for the betterment of civic life," and had no other purpose in this investigation than to see that the people of the county get a system of serviceable roadways at a cost which is not too great. While some of the earlier work in the county was admittedly not as good as it should be, the club felt justified in commending the concrete road, especially in view of its reasonable cost as compared with other materials. The report makes the following comparisons:

"Among possible substitutes for concrete roads are asphalt, brick and macadam. Asphalt costs about 65 cents more per square yard than concrete. Furthermore, asphalt requires frequent kneading, such as is furnished by regular traffic, in order to preserve its texture and prevent crumbling. Some county roads are too little traveled to afford this kneading. Dirt is usually tracked onto the county pavements from cross roads and ditches. Traffic would knead this into the asphalt on the traveled roads, and as a result asphalt roads would tend to go to pieces rapidly.

"Brick pavements cost on the average of $1.25 more per square yard than concrete.

"The initial outlay for macadam is 50 cents per square yard less than the cost of concrete. Macadam, however, goes to pieces rapidly under heavy teaming or under automobile traffic. The former produces ruts and holes which require frequent repairing. The latter sucks up the fine stone which binds the roads and whirls it away in a cloud of dust, leaving only the skeleton of the pavement. Concrete is practically dustless. Since automobile traffic is constantly on the increase, concrete roads have a great advantage in this respect. They also exert less resistance to the vehicles passing over them. Concrete roads will enable regular auto truck service to be established through the country districts.

"The average cost per square yard of these types of pavement, as estimated by the county highway commissioner, are: Macadam, 85 cents; asphalt, $2; brick, $2.60; concrete (1914), $1.35, (1913), $1.55."

Ease of Cleaning. The fact that Mr. Tillson assigns to this item a value of 15 is conclusive proof that he has city pavements primarily in mind. Even under this high valuation, however, concrete pavements can qualify for a place equal to any. The fact that concrete is laid in large units is of itself perhaps a sufficient recommendation on this point. This gives broad expanses of reasonably smooth surface to be cleaned, free from frequent joints, and the irregularities in surface which always result from the use of small units—surfaces easily cleaned with brooms or mechanical cleaners, or flushed with a hose. The only pavement to which it can be compared in this respect is sheet asphalt; but this latter acquires so much unevenness of surface in the course of a few years, due to the unequal bearing strength of the various parts of the subgrade, that water does not readily flush it clean, and thorough cleaning with mechanical cleaners is almost out of the question. The concrete pavement, on the other hand, both by reason of the fact that it retains its true shape indefinitely, and because of the nature of its surface, is admirably adapted to the economy of mechanical cleaning.

Col. George E. Waring, Jr., when street cleaning commissioner of New York City, made the statement that he could save the city $500,000 a year in the cost of cleaning if all the streets were paved with asphalt. Concrete pavement was not known at that time; but with its advantage over asphalt, as above pointed out, concrete could be expected to effect an even greater saving.

Resistance to Traffic. By this is meant the amount of friction developed between the pavement and moving vehicles, this factor governing the load which any given power can haul over a road. As the amount of this friction varies with different materials, it stands to reason that the most economical roadway, other things being equal, is the one in which this friction is least.

Prof. Arthur H. Blanchard, of the Highway Engineering Department of Columbia University, considers sheet asphalt as the perfect pavement in point of ease of traction, assigning it a value of 10 on this point in making up the characteristics of an ideal pavement. To concrete he gives a value of 9, and to earth roads 2, other materials taking various intermediate values. He has given concrete a high place, to be sure, giving a better rating to only one other material; but we believe even this scarcely warranted. The elasticity and resiliency of asphalt do not make for ease of traction, but rather the reverse; for an asphalt pavement, with its slightly yielding surface, is a nearer approach to a dirt road than an unyielding surface of concrete. Granting Prof. Blanchard to be correct, however, his rating could only apply to a perfect asphalt surface, true to line in every direction, which is something seldom to be found, and which the pavement rapidly departs from, even if conforming to it when first laid. On the other hand, as already pointed out, concrete holds its original shape, subject only to slight and usually uniform wear.

Taking it in another way, it may be stated that to move a weight of one ton will require a tractive force of 100 pounds on a dirt road, 40 pounds on macadam, 25 pounds on brick pavement and 20 pounds on concrete; in other words, that a horse on a concrete roadway can draw five times as much as on a dirt road and twice as much as on macadam.

Non-Slipperiness. This is a factor which is more under the control of the builder in concrete than in any other material, it being possible to make the surface of almost any desired texture.

Ease of Maintenance. While we continue to follow Mr. Tillson's headings, this might perhaps better have been "Cost of Maintenance," although each term may by inference be made to include the other. It is the cost of maintenance, however, which goes into the records of a municipality, and by which the success or failure of a pavement will very largely be judged as the years go by. On this point alone concrete is destined to win a vast number of friends as its low maintenance cost becomes generally known.

Consider for a moment this question: What is the maintenance cost of a well-laid basement floor or properly constructed concrete sidewalk? True, some floors will require an occasional patch and some walks an occasional square replaced; but equalize these charges over the total life of the structure and it will be found that the annual charge is very small indeed. So it is with a concrete roadway—the first cost is practically the only cost, requiring ridiculously small appropriations for maintenance, and allowing municipalities and road districts to spend most of their money on new construction.

The oldest concrete pavement of which the writer has knowledge was built at Bellefontaine, Ohio, in 1893 and 1894. This pavement contains 4,400 square yards and was built in two courses. On December 14, 1912, Mr. C. A. Inskeep, city engineer, stated that the approximate total cost for repairs had been $200.

When laid the pavement was cut into squares, similar to those commonly seen in cement concrete sidewalks, and the principal part of the wear has been along the longitudinal joints thus formed. The wheels of vehicles form grooves at these places which they have a tendency to follow.

If the reported figures are accurate, the total repair cost has been only 4.77 cents per square yard in 18 years, or 0.265 cent per square yard per year.

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1912, the highway commissioners of Wayne County, Mich., state: "The only surface repair required on our concrete roads has been the refilling of the contraction joints with tar and sand on the roads first constructed, where the joints were not protected with armor plates. The cost of refilling these joints did not add to exceed $100 all told to our maintenance costs."

The maintenance cost of an asphalt pavement runs from 5 to 35 cents per yard each year, depending on the quality of the first installation and the state of repair demanded by the city. In some thickly populated districts the maintenance of a macadam pavement has been known to cost as much as the original construction, meaning a practical rebuilding each year.

Figures collected by the Office of Public Roads relative to the cost of maintenance of plain macadam and bituminous macadam pavements under fairly heavy traffic conditions indicate that these pavements, when properly maintained, entail an annual absolute maintenance charge of approximately $450 per mile per annum for plain macadam, and possibly from $800 to $1,000 per mile per annum for bituminous macadam, for 15-foot surfaces. These figures have led Mr. Logan Waller Page, director of the Office of Public Roads, to believe that we must seek a more permanent form of pavements for country road surfaces.

Favorableness to Travel. By this is meant the ease and comfort of riding, as well as the reduction of wear and tear on vehicles to a minimum. The fact that concrete is placed in large and unyielding sections is perhaps a sufficient argument for it in this regard. There is not the frequent recurrence of joints found in many other types of pavement, tending to wear the vehicle and reduce the comfort of passengers, even when such a pavement is at its best; while the deterioration of many small units, the rounding of the edges and the gradual settling in spots as traffic progresses, produce an increasing unevenness and corresponding discomfort. A concrete pavement not only presents a broad expanse of unbroken surface, as has been spoken of before, but it has within itself sufficient strength to bridge over weak spots in the sub-grade.

In October, 1911, Mayor Gaynor of New York appointed a special committee on pavements, to investigate and report to him on the condition of the pavements of that city. In making its report this committee said:

"No quality which a pavement can possess is more important than smoothness. Every irregularity in the surface is a source of weakness and of ultimate failure. As the wheels are drawn over the road, the wear which they cause is almost in proportion to the obstacles encountered. If the pavement is rough, as our stone ones are, or if it be broken, the wheels pound, and the pavement is subjected to heavy blows which soon wear it away and otherwise destroy it. In almost all our stone pavements one can find places where the blocks have actually been crushed or split from this cause. If the pavement is of wood block, asphalt or any other composition material, and the surface is wavy, the depressions will hold water and speedily lead to failure; in such pavements disintegration almost invariably commences in these places. In macadam roads, depressions of this sort are the chief cause of wear, and especially so since the introduction of the automobile.

The rapidly passing wheels throw out the standing water with great violence, carrying with it the binder or fine stuff between the stones, thus causing the pot holes which make their appearance so rapidly on such roads when subjected to heavy automobile traffic.

"It should be remembered that since the advent of the automobile, smoothness for pavements is an even more important quality than it was formerly. The shock which a swiftly moving vehicle receives when it meets an obstruction, is more violent and destructive in its effects than if it were proceeding at a more moderate gait, and no matter how the force of the blow may be disguised from those riding in the car, by springs, pneumatic tubes or otherwise, the destructive effect of the blow remains the same and is absorbed by some part of the mechanism, causing injury either to the tires or frame.

"The loss sustained yearly by the citizens who use automobiles, by reason of the roughness of our pavements, must be very great in the aggregate."

The increased use of rubber tires constitutes one of the leading reasons for the rapid rise of the concrete road. There are already many highways where 90 per cent or more of the traffic consists of rubber-tired cars, and while the rubber tire is exceedingly destructive to a waterbound macadam road, it has little or no abrasive effect on a hard, smooth surface of concrete. Wherever automobile traffic constitutes the great bulk of the travel, therefore, the concrete road will show greatest durability and will give the most general satisfaction.

Sanitariness. On this last point it will readily be conceded that concrete has no equal as a road and pavement material. It contains in itself nothing which can decompose or become objectionable; it offers neither a porous surface nor numerous joints for the collection of street refuse, where it can decay and become a menace to public health. Any liquid refuse which might penetrate the surface of a concrete pavement, which will be smaller in amount than on any other class of pavement with the possible exception of sheet asphalt, will, to a large extent, be neutralized and made harmless by the lime in the concrete.

It has at times been freely intimated that the present popularity of the concrete road is due in large measure to the energetic propaganda of some of the cement manufacturers. While this may be very true in one sense, it is not true in the sense in which the detractors of the concrete road would have us believe; that is, the popularity of the concrete road is not resting upon a forced and unnatural foundation built up solely on advertising. The cement manufacturers and their engineers understand perfectly that they cannot build up a permanent market for cement in this field unless the concrete road can be made a permanent success, and they have directed to its perfection all the technical skill which they have been able to command, until even those who in the beginning were either lukewarm or openly hostile in the matter have come to acknowledge that the concrete roadway will be at least one of the leading types, if not indeed *the* leading type, in future roadway construction.

CHAPTER II.

The Various Types of Concrete Roadways.

Broadly speaking, there are, as is perhaps commonly known, two general types of concrete pavements, designated by the terms *One Course* and *Two Course*. The former of these is made of one mixture of concrete throughout and placed in one operation, while the latter has a base of a lean mixture, with a wearing surface richer in cement and usually with a harder and more wear-resisting aggregate.

While it may be said that the one-course roadway seems to be growing in favor, and should be employed wherever practicable, the determination of the type to be employed must be governed largely by local conditions. If, for instance, the aggregate most readily available is of a soft nature and readily crumbles under abrasion, a better and more economical pavement will be secured by using this in a base course, with a wearing surface in which granite or some other hard rock is used as an aggregate. This small amount of granite will take the wear of traffic, while the bottom course, with a local aggregate, will have sufficient strength for a foundation. Some cities which are putting in large amounts of concrete paving, such as Mason City, Iowa, find it advantageous to follow this method. In other localities, where there are available deposits of hard gravel or other stone suitable for this work, which does not have a sufficient market value to make its use extravagant, a one-course roadway can be laid to good advantage. While this type requires perhaps more cement to the yard, the labor cost is somewhat less. In localities where cement is high in price, however, these items will have to be balanced against each other, though it will probably be found that any difference will be in favor of the one-course type in almost every case. This type also leaves no possibility for the separate of the wearing surface from the base, as may happen in a two-course pavement if sufficient care is not exercised in laying.

The selection of a particular type to be used in any given locality is therefore a problem for both an engineer and an economist. It is, of course, necessary, from the standpoint of economy and public interest, that local material be used as far as possible. One of the great advantages of concrete roadways is the fact that local materials can be so utilized, thus not only patronizing home industries, but saving heavy freight charges on materials which otherwise would have to be shipped in from some distance. On no account, however, must concrete be put upon streets which is composed of unsuitable materials, for in the end the very purposes would be defeated for which the materials were so used. This subject is treated further in the chapter on "Materials for Concrete Roadwork."

In addition to these two main types of concrete roadwork, there are various forms of reinforced concrete pavements, patented concrete pavements, as well as the use of concrete in combination with other materials, such as bitumen or asphalt, for wearing surfaces. All of these are treated in appropriate chapters farther along in this volume.

In one or two cities the experiment has been tried of building a concrete pavement in two courses, with a sand cushion of one or two inches between the courses; in other words, the pavement is treated just the same as a brick pavement on concrete base, with a sand cushion under the brick. Pavements of this type are claimed to be giving good results.

A concrete pavement differs from other pavements in cross-section in that it is usually given a flatter crown. Concrete pavements are not damaged by water, so that they could be made perfectly flat were it not for draining off the surface water to keep it away from traffic. A perfectly flat roadbed would be preferable so far as traffic is concerned, as it would tend to equalize the wear on the pavement, distributing the traffic on it more evenly. An approach to a flat surface is, therefore, to be desired. The crown of a concrete pavement need only be sufficient to drain it and prevent the formation of thin sheets of water or ice on the surface. For this purpose a crown of from 1/10 to 1/50 of the width of the pavement is all that is necessary.

While concrete city pavements are, of course, laid from curb to curb, the same as any other type of pavement, roadways are usually built with a slab of from 8 to 18 or 20 feet wide in the center of the road, and with shoulders of gravel at the sides. It would manifestly be impracticable to allow the concrete to run down to a thin edge at the sides of the road, as these points would be broken off by the traffic. The plan is adopted, therefore, of finishing the roadway with gravel shoulders, as above referred to, allowing them to taper down from the edge of the paving to a thin edge about 4 feet away.

CHAPTER III.

Preparation of the Sub-Grade.

The one important requirement that must be continually kept in mind in preparing the sub-grade for a concrete road or pavement is that it must be uniformly compacted. It is perhaps not as necessary that it be compacted to a great density as it is that the density, whatever it is, shall be uniform throughout. In fact, there are road builders who contend that the sub-grade should not be compacted to a greater density than the normal density of the ground around it. Their theory is that the ground will tend eventually to return to normal, and that a strain, tending to crack the concrete, will be the result. However this may be, road builders are agreed that the density must be uniform and that considerable effort and expense are worth while in order that this may be secured. It is sometimes argued that the strength of a concete slab will be sufficient to bridge over any soft spots in the sub-grade; but it is very easy to overestimate this strength of the slab, and it is so easy to bring the subgrade to uniform density that this action of the slab should not be depended upon.

Commercial traffic over streets and roadways is continually becoming heavier, and the tendency seems to be to carry still heavier loads as the highways are improved. It must be remembered, too, that the entire load of a vehicle rests upon four points, represented by the points of contact between the wheels and the pavement. With a load of several tons distributed over these four points only, the strain which is occasioned by the wheels coming over a soft spot in the sub-grade can be well undertood.

The sub-grade may be either flat or curved to the crown of the finished road. In the first case this of course gives a concrete slab which is thicker in the middle than at the edges, while in the latter case the concrete slab has a uniform thickness throughout. In the first edition of this book the author stated that the latter method was perhaps more frequently followed than any other. At the time of this revision, one year later, there is a decided tendency among road builders to build concrete roads with a flat sub-grade, thus taking advantage of the additional strength in the middle of the slab just where it is needed. Engineering authorities are practically agreed that this is the best form of construction, and it is probable that it will, before long, come into almost universal use.

A plotting of the strain on a concrete pavement will show that a pavement on a flat sub-grade has an even greater proportion of strength than simply that given it by the added material. Without any diagrammatic plotting of the strains, however, it can be seen readily that such a pavement is in a greater state of repose than a pavement on a crowned sub-gade. A flat sub-grade also facilitates the "crawling" of the pavement, due to expansion and contraction, and thus lessens the tendency to crack.

For this latter reason, too, the sub-grade should be smooth and free from humps or depressions. Soft and spongy places must be removed and filled in with the same material as the body of the road. The sub-base should be kept wet while being compacted, and also should be thoroughly wet when the concrete is deposited, in order that the water in the concrete may not run away.

Particular care has to be taken where concrete is built over an old road or pavement of any kind. A concrete road requires less crown than almost any other kind, so that if the old crown of the road is left as it is, the concrete slab will very likely be thinner in the middle of the roadway than at the sides. This is readily recognized as a source of weakness, producing a tendency toward the opening up of longitudinal cracks down the center.

In the cast of dirt roads, this is obviated at times by removing part of the material in the center of the road by means of a scraper or grader and placing it on the sides. This, too, offers an opportunity for weakness in the sub-base, because of the fact that the old part of the roadway in the center will be more densely compacted than the newer parts at the sides, and this also will give opportunity for longitudinal cracks. In a case of this kind it is better either to cut the road down in the middle to the crown of the finished concrete, or preferably to a flat sub-grade, removing the surplus material; or else tear up the entire road and roll it again, thus insuring a uniform density throughout.

In the case of an old macadamized road, or other kind of hard pavement, which is to be used as a subbase for concrete pavement, and which would be difficult and expensive to remove, the most economical practice would probably be to use it as it is, covering it with a concrete slab of equal thickness throughout.

This will give the concrete pavement the same crown as the old pavement, which will probably be greater than necessary, but which will result in a good road at minimum cost.

The drainage of the roadbed of a concrete pavement is of vital importance. If the sub-grade is not well drained, there is danger that after the concrete is laid, the drying of the soil under the edges of the concrete may permit the pavement to settle and thus cause longitudinal cracks on the surface. Further, if the sub-grade is not well drained, there is a possibility that the frost may lift the edges of the concrete roadway and cause longitudinal cracks.

If the soil is sandy, there is a probability that the natural under-drainage is sufficient for the purpose. Where underground water is likely to be present, it is necessary also to lay a line of ordinary farm tile on one or both sides of the pavement. The tile should be at least 4 or 5 inches in diameter, and should be laid 2½ to 3 feet below the surface. The tile drain should have sufficient fall to free itself promptly and fully. It is better to lay the tile outside of the edge of the concrete slab than under it. Some engineers put a layer of coarse gravel or broken stone immediately above the tile to facilitate the entrance of the water into the tile; but such precautions are unnecessary except to aid the entrance of the water directly into the tile. Ground water always enters the tile from below.

If the soil is only moderately retentive, it is recommended that a shallow longitudinal ditch be constructed just outside of the edge of the concrete slab. The ditch should extend about 8 or 10 inches below the surface of the roadbed, that is, below the bottom of the concrete slab, and should be filled with coarse gravel or broken stone. From this longitudinal ditch short transverse ditches should be dug across the shoulder to the ditch at the side of the roadway. These tranverse trenches should have a grade sufficient to permit them to carry the water promptly and fully to the side ditch. In particularly retentive soil these transverse trenches should not be placed more than 50 feet apart. On level stretches these transverse ditches should be practically at right angles to the direction of the road; but if the road is on a grade, these trenches should make an acute angle with the roadway, the amount of this angle depending upon the grade of the road. The sloping of these lateral trenches downhill makes it unnecessary to have the ditches at the sides of the roadway as deep as would otherwise be required. These lateral ditches should be filled level full with broken stone or coarse gravel to a point at least a little beyond the outer edges of the shoulders and preferably nearly to the bank of the ditch at the side of the roadway.

A careful checking of the elevation of the foundation at frequent intervals of, say, 2 or 3 feet, by the use of a straightedge or string, resting on or stretched from the top of the side forms, and a rule, is important in order to insure the proper thickness of the finished concrete. This may seem like an unnecessary requirement; but variations of less than 2 inches cannot usually be detected by the eye, and failure to check the foundation as outlined may result in decreasing the thickness of the pavement at the center 25 per cent or more, where full strength is absolutely essential.

CHAPTER IV.

A Discussion of Materials.

The materials for concrete road work which are primarily to be taken into consideration are water, cement, fine aggregate and coarse aggregate.

The first two need enter but very slightly into this discussion. The water should of course be reasonably clean, free from oil, alkali, acid or organic matter; that is, it should contain nothing which will interfere with the setting of the cement, or tend to weaken the concrete. Regarding the water, it must also be suggested that provision must be made for securing a sufficient supply. The mistake is often made of starting concrete road work without any adequate provision for water supply. In addition to the water which enters into the mixing of the concrete, it must be remembered that water is required for wetting down the sub-grade, as well as for sprinkling the concrete for several days after the road is completed.

Regarding the cement, it is sufficient to say that it should pass the standard specifications adopted by the American society for testing materials.

It is to the coarse and fine aggregate that the greater part of the attention of engineers and road builders must be directed. Unless these materials are right, well chosen, properly proportioned and clean, the resulting roadway is doomed, if not to absolute failure, at least to but a partial success, and it will have entailed upon it an annual maintenance charge which will much more than overbalance any additional first cost for a more careful selection and preparation of materials in the first place.

It would seem as though it should not be necessary to lay so much emphasis on this matter of correctly selecting and preparing the aggregates for concrete road; but observations made by the writer and by a large number of others who are interested in the development of the very best type of concrete roads seem to make this necessary. In a large number of cases have builders started out to build concrete roads by using bank-run material, believing that the concrete was being laid in a sufficiently large mass to give it strength, even though the aggregate might contain elements of weakness, either in its composition or in its gradation of sizes. Some of these men have been willing to confess subsequently that they were mistaken and have constructed later work with washed and screened materials. This was done of course at a slightly increased cost; but they could see very plainly that the increase was justified, in view of the fact that maintenance or reconstruction charges on the earlier work had already commenced.

The writer feels inclined, therefore, to urge all builders of concrete roads and pavements to profit by the experience of these men, and not to undertake such construction without a careful examination of their material and without reasonable certainty that they are correct.

Regarding the fine aggregate, it seems paradoxical to say that it should not be too fine. It is well known that an excess of fine material decreases the strength of concrete, but it is especially deleterious in concrete roadways, because of the fact that this fine material very largely rises to the surface and does not resist successfully the abrasive action of traffic. A fine aggregate, therefore, must be always tested for its fineness, and must be properly graded from fine to coarse, not more than 5 per cent of it passing a sieve having 100 meshes to the lineal inch. From this size it will run up to ¼ inch. It is not sufficient, however, to specify simply the extreme sizes of the fine aggregate, as will be noted from the standard specifications of the American Concrete Institute. These specify that not more than 20 per cent shall pass a sieve having 50 meshes per lineal inch, and in some specifications a still more careful gradation is insisted upon. This specification holds good for both one and two-course work; it is also specified that fine aggregate containing more than 3 per cent of clay or loam shall be washed before using, and that briquettes made one part Portland cement and three parts fine aggregate, by weight, shall show a tensile strength at least equal to the strength of mortar made with the same proportion of standard Ottawa sand.

No matter what the gradation of particles or the tensile strength, however, the fact must be continually kept in mind in the selection of all materials for concrete roadways that they must be suited to withstand the abrasion of traffic, or they should not be allowed to enter into such work.

For the fine aggregate, therefore, there should preferably be used a good bank sand, with coarse grains predominating, or the screenings from clean, hard, crushed rock or gravel. The screenings from ordinary limestone cannot be considered in any sense a satisfactory fine aggregate, especially for a wearing course.

A coarse aggregate of hard quality is necessary to resist the wear and abrasion of hoofs and wheels. Failures of concrete roads have been caused simply by the softness of the coarse aggregate. In one instance, for example, shells were used for the aggregate, and the road went to pieces as soon as it was subjected to wear. All stone like shale, slate, shells and soft limestone must be rejected, while granite, trap and conglomerates are especially suitable material. In some localities a hard limestone is obtainable, such as that occurring along the Hudson river, which is sold in New York as trap rock. This cannot be cut with a knife and has a specific gravity of over 2.7. Gravel does not bond quite so strongly with cement as does broken stone. However, when properly screened and free from dirt and remixed with sand in the proper proportions, a good concrete can be made from it, even for a one-course roadway.

The size of the coarse aggregate should be such as to pass a 1½-inch opening and be retained on a screen having ¼-inch openings. It should not contain any large proportion of flat or elongated particles.

If two grades of aggregate are used for the wearing course of a two-course pavement, the coarse aggregate will be from ¼ inch up to 1½ inches in size.

In both fine and coarse aggregates care must be taken that no lumps of frost or frozen material are used.

Experiments with Puzzolan Mixtures. In 1912 and 1913 some experiments were carried on under the direction of Mr. E. H. McAlister, dean of the School of Engineering, University of Oregon, to determine the

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,400	85,370
,400	38,500
,700	621,840
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,200	35,000
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,800	58,200
,200	580,785
,600	59,000
...	19,200
,000	655,650
,400	....
,100	189,450
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,700	20,000
,600	21,000
,930	80,740
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value of puzzolan mixtures with cement as a possible economic expedient in the construction of concrete roads.

It has been known to scientific experimenters for some time that if certain volcanic materials be reground with Portland cement, the resulting blend can be used to make concrete which in point of strength is equal or superior to concrete made in the usual manner. A material saving is effected in cost, especially where cement is high in price.

From the known chemical composition of certain volcanic materials abundant in Oregon Mr. McAlister inferred that possibly some of them might have good results when blended with cement, and accordingly undertook a series of tests at the civil engineering laboratory of the University of Oregon.

From these tests it has been found that blends composed of equal parts by weight of cement and puzzolanic material have somewhat less strength in compression than the original cement, but that blends composed of 2 parts cement to 1 part puzzolanic material by weight have far greater compressive strength than the original cement. However, it must be noted that all the puzzolanic materials experimented with are lighter than the cement, so that equal parts by weight give an excess of puzzolanic material by volume, and the results obtained indicate that 53 per cent by weight of cement to 47 per cent "Eugene puzzolan" will give compressive strength equal to that of the original cement in either 1:3 or 1:5 mortars; while equal parts by volume of cement and diatomaceous earth will surpass the original cement.

CHAPTER V.

Economic Methods of Handling Materials.*

The materials to be handled in the construction of a concrete road are:

(1) Water,
(2) Cement,
(3) Sand, and
(4) Gravel or Stone.

Water. The first mentioned material, water, is quite apt to be given scant consideration by the road builder whose experience has been limited to work within cities or villages. Likewise the engineer or contractor who has never before attempted road construction is prone to underestimate the cost of securing and delivering water, whether for concrete or macadam roads in country districts. In arid regions a mistake of this sort may readily result in serious financial loss.

Water, it should be remembered, is used for at least three purposes in building concrete roads: (1) to wet the subgrade; (2) to mix the concrete; and (3) to keep the concrete moist for several days after it is laid. On a sandy subgrade that must be wet and rolled before laying the concrete, as much as 100 gallons of water per cubic yard of concrete may be used merely to wet the subgrade. Then an additional 50 gallons

*This chapter is taken almost entire from the report of Committee Number 10, presented at the National Conference on Concrete Road Building, held in Chicago, February 12, 13 and 14, 1914. The report was presented by Mr. Halbert P. Gillette, chairman of the committee, the other members being Mr. Donald D. Price and Mr. Percy H. Wilson.

or more per cubic yard will be required to mix the concrete wet enough to flow readily. Finally as much as 80 gallons per cubic yard of concrete will be needed to keep the concrete wet for a week after it is laid, if the air is very dry and if there is much wind. A total of 230 gallons of water, weighing 1,900 pounds, has been required for each cubic yard of concrete, in one case which is on record. More than that would have been used had the concrete not been kept covered with a layer of earth an inch or more thick. The earth, of course, retarded the evaporation of the water. The water in this case was hauled in tank wagons, so there was no guessing as to the total amount used.

A ton of water per cubic yard of concrete may probably be regarded as the maximum that need ever be required. A quarter of a ton of water per cubic yard is probably the minimum, if there is to be any sprinkling of the subgrade and of the concrete. A 2-mile haul at 25 cents per ton-mile results in a cost of 50 cents per cubic yard of concrete for hauling the water where the maximum amount is needed. This is astonishing indeed to the contractor who has been accustomed to mix and place concrete for 50 cents a cubic yard under certain conditions.

When large quantities of water are to be moved considerable distances, pipe lines should usually be laid along the road and the water should be pumped. Quite a common mistake, when this is done, is to use pipe of such small diameter that the friction head makes it impossible to deliver the quantity of water needed. Thus a 1-inch pipe is often laid where a 2-inch pipe is needed.

Cement. In the handling of cement there are two very common economic errors in evidence: (1) failure to provide a large stock of cement; and (2) an attempt to locate the cement nearer the concrete mixer than is necessary. The concrete road builder is so often forced to wait for the delivery of cement by rail that he eventually learns that it pays to tie up more capital in a stock of cement than to foot the bills incident to delays in securing it by rail. Although cement dealers are usually prompt in making shipments, the railways are not always to be relied upon. For this reason, cement should be accumulated in stock-houses or stock-tents. Tents, with wooden floors made in sections, can be placed at short intervals along the road. From them the cement can be delivered in small gasoline motor cars of the kind that cost about $500 each. Such a car will carry 10 or 12 bags of cement and can be run into the tent to be loaded by the driver of the car. The car will travel from 15 to 20 miles an hour loaded and 18 to 25 miles an hour empty, at a total cost of about 4 cents per car-mile one way or 8 cents per car-mile of effective hauling work. The resulting cost of hauling cement short distances can not be equaled in any other way.

Sand. After the subgrade has been sprinkled and compacted by rolling, it is customary to dump sand and gravel on it in piles. Then these materials are loaded into barrows and wheeled to the concrete mixer, which travels along the subgrade, leaving the layer of green concrete behind. This seems to be at present the most common way of placing concrete. But it is not the only way, and there are some contractors who maintain that it is not the cheapest way. Another method is to place both the mixer and the stock piles on one side of the road. The materials are then usually shoveled directly into the mixer, or into a bucket or skip that delivers into the mixer. In the west it is not unusual to see Fresno scrapers used to drag the sand and gravel from the stock piles to the mixer. In some cases the scrapers deliver the materials upon a platform, whence they are fed by gravity into a skip that delivers into the mixer. In these cases the mixer is not moved until about 600 to 1,000 feet of road have been built in both directions from the mixer, the concrete being hauled in one-horse concrete carts or in one-man concrete buggies.

The differences in cost between these two methods seem ordinarily not to be very great; but there may be conditions that justify a choice of one method in one place and of another method in another place. Thus, if laborers are scarce and mules or horses plenty, the latter method may be preferable.

So much has been written about the unloading of cars of sand, etc., with drag scrapers, clam shell buckets, and the like, that we shall not here go into these labor-saving methods. An ingenious modification of old methods was recently described. It consists in dumping sand or gravel from a hopper-bottom car into a pit dug beneath the track. The materials are thence dragged with a power-scraper up an incline and dumped into a bin. This method has much to commend it where hopper-bottom cars are available.

Gravel and Stone. Although cement and even sand may be rehandled without adding greatly to the cost of a concrete road, an attempt should always be made to avoid rehandling the gravel or broken stone.

Broken stone is particularly hard to shovel up when dumped on the ground; and besides, it constitutes a very large part of all the materials to be handled. Stock piles of sand may often be needed to avoid delays in freight shipments; and in such cases, they may be placed at relatively short intervals along the side of the road. If broken stone or gravel is also received by rail, it is generally wise to build the stock pile at the place where the cars are unloaded. Then a clam shell bucket can be used both to unload the cars into the pile and to load the wagons from the pile.

If large stock piles of stone or sand are to be made along the road, care should be taken to scrape a smooth place upon which to build the pile. With a road machine and a roller, a place can be so graded and compacted that very little of the material in the stock pile will be lost. Care should be taken to locate such stock piles where heavy rains will not wash the materials away.

In the handling of broken stone from portable rock crushers, two economic errors are common: (1) bins are too small; and (2) their bottoms are not steep enough. Small bins make it necessary to stop the crusher if there is not perfect coordination in hauling and using the materials. Bottoms that are flatter than 1 to 1 prevent the stone from running rapidly, and thus delay the loading. This last is important enough with team-hauling, but it is much more important where motor trucks or traction engines are used.

CHAPTER VI.

Mixing and Placing Concrete.

The determination of the proportions in which the materials are to be mixed is a most important consideration, and when once determined it should be insisted upon with the utmost uniformity. The contractor who is in the habit of increasing his profits by saving cement when the inspector is not around has no place in the construction of concrete roadways. He should not only have good intentions in this regard, but his equipment and organization should be such that he may know that this proportion is being kept up with unceasing regularity.

The actual proportions to be used will be likely to vary somewhat with each case, and should not be determined upon arbitrarily, but should be made a matter of investigation after it has been decided what materials are to be used. In Wayne County, Michigan, various proportions have been tried at different times, the road builders of that county finally arriving at a mix of 1 : $1\frac{1}{2}$: 3 as the best for a one-course roadway with their materials. If a hard-and-fast rule were to be adopted, this would probably be as good a one as could be used; but as we have tried to point out elsewhere in this volume, and as is coming to be pretty generally recognized on all kinds of concrete work, the making of concrete is not one of fixing an arbitrary rule for all cases, but of combining the particular materials in such a way

... in the Construction of a Concrete Road as to fill all the voids and make the densest product possible.

The American Concrete Institute has allowed a certain amount of latitude in its specifications, prescribing that the proportions shall be 1 bag of cement to not more than 2 cubic feet of fine aggregate and not more than 3 cubic feet of coarse aggregate, and that in no case shall the volume of fine aggregtae be less than one-half the volume of the coarse aggregate. The specification goes further and states that a cubic yard of concrete in place shall not contain less than 1.7 barrels of cement.

These specifications are absolutely safe, and will make a highway or a city pavement which will give good service under traffic. In fact, most of the roadways being laid at the present time which are a delight to their builders and which are approved by competent authority as being dependable in every way, are laid according to specifications which approximate these as regards the proportioning of materials.

A proportion of two terms, such as 1:5 or 1:6, is not to be considered, especially for a one-course roadway, for a proportion of this kind means that the run of the pit, or run of the crusher, is being used, rather than having the materials properly graded into coarse and fine. It is perhaps conceivable that pit-run material might be found which would do very well for the base of a two-course pavement; but when it is remembered that the base course must very largely give the pavement its strength against temperature changes, unequal loading and the like, the need for the best class of concrete will make it worth while to carefully grade and proportion the materials here also.

Referring again to the specifications of the American Concrete Institute, it will be noted that on two-course work only the amount of cement per cubic yard is specified, this being 1.4 barrels for the base and 2.97 barrels for the wearing course. Provision is made, however, for a very close checking of the amount of cement by the engineer, and for the taking up and relaying of the work if the cement goes to any appreciable percentage below the amount specified.

It is obviously unnecessary to say that on work so important as this the utmost care should be exercised in having the concrete mixed thoroughly. A badly mixed batch of concrete will be sure to mean a pocket of stone and sand without sufficient cement to hold it together. If this pocket comes to the surface of the roadway, it will very soon be pounded out by the traffic and washed away by the rains; while if it should be concealed below the surface it would be no less a source of weakness, though perhaps not producing disastrous results quite so rapidly.

In the first edition of this book considerable space was given to a comparison of the economic efficiency of machine mixing over mixing by hand. It does not seem necessary to include this matter in this edition, inasmuch as machine mixing is now universally used on this class of work, and is well recognized as not only producing superior results, but as placing the concrete at a much lower price than is possible with hand labor.

The growing importance of the concrete road and pavement is attested by the fact that the manufacturers of mixers are rapidly adapting their machines to the particular demands of this class of work. These demands include large output, ease and rapidity of charging, deliver as near as possible to the point of deposit, and ready movement of the machine from one point to another. A number of machines are now doing this work with a high degree of efficiency, although it is possible that the next few years will see still greater improvements, especially in the methods of loading the mixer, and in the design and gearing of the machines so as to develop the best possible mix. The matter of the time of mixing, and the number of revolutions per minute at which a mixer shall run in order to produce the best concrete, are matters which are just now being taken up by some engineers with a view to working out standards of practice, and while some specifications for concrete roads and pavements attempt to specify these things, there is probably as yet scarcely a sufficient amount of data on which to base positive conclusions.

The materials will usually be placed along the line of the roadway in separate piles, the large aggregate on one side and the small aggregate on the other. The placing of the loads should be quite carefully figured out beforehand, so that as nearly as possible the right amount of materials may be placed ready for use. If the amount is allowed to run low, it will mean that long runs of the wheelbarrows will at times have to be made, and that additional loads of materials will have to be hauled in, interrupting to a considerable extent the orderly and constant movement which should be maintained in order to attain the greatest efficiency in this kind of work. On the other hand, if too great an amount of material is placed along the line of work, it will seriously impede construction, causing an occasional stop of the mixer while a wagon comes in to carry away the surplus. In order to gauge accurately the placing of the materials, wagons of a standard size and carrying a uniform load should be used. It will then be an easy matter to calculate from material tables the amounts required, and to approximate these amounts very closely in the spacing of the loads.

The method of proportioning the materials in perhaps most general use, unless an automatic proportioning mixer is used, is to measure them in the wheelbarrows in which they are wheeled from the piles to the mixer—so many barrow loads to so many sacks of cement, according to the proportions which have been worked out for the particular aggregates in use. Sometimes, however, the materials are shoveled directly from the piles into the hopper of the mixer, when the mixer is close enough to the piles to make such a method feasible. This, of course, can be done successfully in the case of an automatic proportioning mixer; but where the shovelfuls are depended upon as a means of measurement, there is so much opportunity for inaccuracy as to make the method most undesirable.

Care should be taken that a mixer is used which will have sufficient capacity to keep the work going in a practically continuous operation. A mixer of small capacity, or a mixer which has seen long service and is likely to need frequent repair, has no place on this clsas of work. A comparatively small crew of men can take care of the output of a large machine, and it is only by having a crew of a size to handle a maximum output, and then keeping the machine up to that output, that the best results and the lowest unit cost can be obtained.

The amount of water to be used in mixing concrete for roads and pavements is something on which there has been much fluctuation of opinion for the past few years. The writer has seen some concrete for this class of construction made almost as dry as that which would be required for a piece of molded concrete from which the mold was to be taken away immediately. Again he has seen the concrete placed so wet that the water stood on the surface and prevented the finishers from seeing whether they were getting a proper grade and finish. Both of these were wrong. The first mistake, that of getting the concrete too dry, is perhaps never made at the present time, largely for the reason that such concrete is much harder to work than where more water is used. But it is possible that we are now going to the other extreme.

There is a tendency on road work to mix the concrete entirely too wet. This causes a separation of the coarse materials and the mortar, resulting in stony pockets through the concrete and on the surface of the road. Where the concrete is mixed too wet, it is practically impossible to maintain the required crown, and stony patches frequently appear on the surface after it has been finished, owing to the flow of mortar to the sides. In striking off and floating concrete mixed with an excess of water, it is also practically impossible to obtain a surface of the desired character, as the excess water collects in and hides depressions and other inequalities in the surface which are not observed until after the water evaporates and it is then too late to refinish.

The matter of consistency is fairly well covered in the specifications of the American Concrete Institute, when it is stated that "the materials shall be mixed with sufficient water to produce a concrete which when deposited will settle to a flattened mass, but shall not be so wet as to cause a separation of the mortar from the coarse aggregate in handling." The concrete should not require tamping, but it must have sufficient body so that it will not flow readily on the sub-grade, but will retain its shape when struck off with the template.

Before the work of mixing is begun, side rails will, of course, be placed to act as forms to retain the concrete in proper position. These side rails may be of 2-inch plank, of a width equal to the thickness required of the concrete slab at the edges, and should preferably have a strip of iron on top to protect them as the template passes over them. In fact, all-steel side rails are sometimes used, and their use will very likely become more general as more efficient means are demanded. But whatever the material used for the rails, care should be taken that they be held in position by stakes at such frequent intervals that they will not be thrown out of line by the pressure of the concrete. These rails, as previously stated, not only act as the side forms, but also form the supports for the template by which the top is struck off, so that they must be in exact line and grade and must be so placed as to retain their position.

With the side rails in position and the mixer and crew ready for action, the next step in the process is to thoroughly wet down the sub-grade, so that it may not absorb moisture from the concrete.

The method of placing the concrete from the mixer will, of course, vary somewhat with the type of machine used. With a machine of the boom and bucket variety, or one with a discharge chute, the concrete can be deposited in almost the exact position desired, right from the mixer; with other types of machines, or in locations where it is necessary to do the mixing at a considerable distance away, the concrete may be transported by wheelbarrows or carts. It should be remembered, however, that it is inadvisable to use horse-drawn carts, as the horses will tend to cut up the sub-grade very seriously. There should be one man who should have no other duty than to direct the placing of the concrete, and in a short time he will get so expert that he will be able to gauge the mater very accurately.

Concrete should not be dumped promiscuously over the surface of the subgrade, but the required depth of concrete for the entire width of roadway should be concreted in as nearly one operation as is practical, distributing and handling concrete with shovels as little as possible. Care should be exercised in placing about the right thickness of concrete so that there will not be a large amount of material to handle with the strike board. Attention in this matter will materially lessen the difficulty and labor in striking off the surface and will result in a very much better surface finish, free from the wavy effect occasioned by the strike board riding the concrete when too much material is placed.

CHAPTER VII.

Finishing and Curing.

The finishing of the concrete consists generally of two processes—striking off with a templet, and a subsequent elimination of irregularities with a wood float. Sometimes the latter process is omitted, especially on narrow country roads where it is possible to handle the templet to good advantage and thus give the road a fairly good surface in the first process, or on pavements where a wearing surface of some other material is to be laid over the concrete.

It should be borne in mind in concrete road work that the aim is not to get a sidewalk finish on the concrete. This not only makes the pavement slippery, but it works too much of the cement to the surface, rather than throwing the wear onto the aggregate, which is supposed to be a material particularly fitted to resist this kind of wear.

The experiment has been tried in a number of cases of brooming the concrete with a stiff broom in order to give it unusual roughness; but the general opinion seems to be that this serves no very good purpose, and that the concrete, by reason of these corrugations cut in it, soon wears down to a smooth surface.

The strike board for road work should be cut to conform to the crown of the finished surface of the pavement and should be of sufficient strength and stiffness as to show no deflection at the center when supported at the ends on the side forms, and no material bowing out of alignment when in use. It should be about 2 feet longer than the width of the road, protected on the bottom edge with metal facing and provided at each end with suitable handles. For roads up to 12 feet in width two 2x6 inch planks dressed on one side and both ends, spiked together, make a good

Covering With Earth.

strike board; and for roads 12 to 20 feet in width, use two 3x8 inch or a 2x10 and a 3x10 inch. A template of such width of face will give better results than one not so wide. Two planks well spiked together make a better strike board and are less likely to warp out of shape than a single piece. The strike board on the narrower roadways should not be too heavy to be easily handled by two men. On wide street pavements it may be necessary to provide for handling by one or two additional men, in which case wire loops can be attached to the board for the men to take hold of and draw it back. They should be so placed as to give a direct pull, rather than a twisting motion.

The strike board should always be worked forward about perpendicular to the axis of the roadway, and as it is moved ahead should be sawed back and forth across the road. At least two, and sometimes additional, passages of the strike board over the surface will be required to produce a finish of the desired character.

The template should be so handled as to give practically the desired finish to the surface. The smoother the surface obtained with the template, the less work will be required with the hand floats. It is very desirable to obtain as much of a finish as possible with the template, because where it is necessary to do considerable of the finishing with wood floats, there is a tendency to work slight depressions into the surface which will not be noticeable until it is too late to remedy them. The use of a steel trowel is not recommended, as the resulting finish is undesirable. The finished surface of the concrete should not vary more than ¼ inch from a 2-foot straight edge, placed upon the concrete in any position.

The finishing of the pavement should be done from a suitable bridge, thrown across the road, and for pavements up to 20 feet in width this is a simple matter. No one should be allowed to step on the concrete after it as been struck off until it has thoroughly hardened. This is especially true on reinforced work, as stepping in the concrete will force the steel out of place.

To reduce the unevenness of surface caused by workmen using short trowels or floats on a road surface, some contractors use a mason's darby, about 4 feet long and 4 inches wide, to give the final surface.

Road Protected by Canvas.

It is well known among all concrete workers that this is a material which should not be allowed to dry out too rapidly. On this score the broad surface which a concrete roadway presents to the sun and wind must be given particular care. Concrete which dries out too rapidly has a softness of surface which would mean disaster to a pavement. It is also much more porous than concrete which is properly cured, and consequently will the more readily be affected by frost. The surface should therefore be sprinkled as soon after it is finished as it is possible to do so without causing it to pit. Some method should also be provided for keeping it moist, either by frequent sprinkling, by covering with canvas, covering with earth or sand, or in some other suitable manner. In some places where it is possible to build up small dikes on the pavement this has been done and the concrete flooded to a depth of about 2 inches. This has an advantage over frequent sprinkling in the matter of labor, while it is also easier and simpler than shoveling off earth after the curing has progressed sufficiently and the road is ready to open to traffic.

The pavement should be kept closed to traffic for from two to five weeks, depending upon the weather conditions. During the summer time, when conditions are favorable to the rapid hardening of concrete, two weeks may be sufficient, but later in the season, when conditions are not favorable, and the temperature ranges from 35 to 50 degrees, and the weather is damp or rainy, a great care should be exercised in throwing the road open to traffic. When the conditions are such that the temperature of concrete when placed is not over 50 degrees, the hardening takes place very slowly. The hardening of concrete is a chemical action, requiring heat, and the hardening will take place in proportion to the amount of heat present, and ceases almost altogether at a temperature of 35 degrees. If at any time during the progress of the work the temperature is, or there is a probability that it will within twenty-four hours drop to, 35° Fahr., the water and aggregates should be heated and precautions taken to protect the work from freezing for at least ten days. In no case should concrete be deposited upon a frozen subgrade. Proper heating of the water and aggregate will enable the concrete to be deposited with a temperature of from 60 to 70 degrees. This amount of heat, and that developed by the concrete in the early stages of hardening, gives the concrete a favorable start, and it is wonderful what such a supply of heat at the beginning will accomplish.

When a concrete road has been laid in the late fall, it is sometimes difficult to determine when it will be safe to throw the road open to traffic. In some cases it may be necessary to open the road before the engineer in charge feels that it would be absolutely safe to do so. Under such conditions, if about 3 inches of straw is placed on the pavement and this covered with several inches of earth, the surface of the pavement may be protected sufficiently to allow the opening of the road a week or two sooner than could be safely done without such protection. Concrete roads have been utterly ruined by opening them to traffic too soon. There is more danger from this source during the late fall than during the summer, because few people realize how slowly the concrete will harden under favorable conditions.

CHAPTER VIII.

The Theory and Practice of Joints.

Almost all concrete roads and pavements are provided with joints at regular intervals, usually termed expansion joints, though this term is probably a misnomer. The joints are in fact provided to take care of contraction rather than expansion, as the concrete is at its greatest bulk when first placed under ordinary temperature conditions, an increase in temperature of nearly 100 degrees being required to expand it to its original bulk after it has once contracted to its normal volume.

These joints, then, are simply provided to bring cracks, which would otherwise occur irregularly, at certain definite points in order that they may be more carefully taken care of and protected.

The theory on which expansion joints are determined was given by Mr. A. N. Johnson, State Highway Engineer of Illinois, before the Highway Congress in Atlantic City in 1912. His statement is as follows:

"Owing to the constant movement of a concrete pavement due to temperature changes, it is impossible to prevent cracks forming. On hot days the pavement tends to lengthen, and on cool days to shorten. It is evident that the cracks form when the pavement tends to shorten. As the pavement moves over the sub-soil, there is developed a frictional resistance which increases foot by foot as added length is given to the section under consideration.

"In a section of pavement of indefinite length, as it tends to shorten under the action of low temperature, a length of the pavement will be pulled over the subsoil, on which the frictional resistance to be overcome just equals the tensile strength of the concrete. When such a point is reached the pavement cracks; thus we can conceive that a section of pavement between two such cracks did not move at the center, but tended to draw towards the center from the ends where the cracks occurred, and that therefore this length of pavement, whatever it may be, represents a section twice as long as the strength of the pavement or tensile strength of the concrete would permit to be dragged over the subsoil or earth foundation.

"If we are to forestall the formation of cracks in a haphazard way, it will be necessary, then, to provide joints close enough together that there will be sufficient strength in the concrete to drag one-half its length between joints.

"If expansion joints are placed from 40 to 50 feet apart, and on the assumption that the coefficient of friction of the pavement with the sub-soil is one, the tensile strength to be exerted as the pavement shortens under low temperature will be 20 to 25 pounds per square inch.

"The advantage of making the cracks beforehand is that their edges may be properly protected from traffic. It will be realized at the outset that the expansion joints constitute the weak points in the pavements, and that there should be as few of them as possible.

"It has been suggested that as concrete sets it shrinks an amount about equal to the expansion due to

70 or 80 degrees temperature change, so that it will be necessary to allow only for arbitrarily weak sections; for instance, a paper joint placed every 50 or 100 feet. As a pavement sets it will shrink and make a sufficient opening to allow for subsequent expansion.

"If the joints become filled with a rigid material, the change in length due to ordinary variation in temperature will result in the development of compressive stresses of about 1,000 pounds per square inch. The deformation that will be produced in the concrete for such stress would about equal the temperature deformation. But a thin slab of concrete of definite length and subjected to compressive stresses of 1,000 pounds per square inch must necessarily buckle.

"If a concrete pavement is laid without expansion joints it might pass the first season without any serious consequences from buckling, as the cracks that are formed by the low temperature might not become sufficiently filled with incompressible material but that they would afford some relief as the pavement expanded under subsequent temperature rise."

The distance apart at which these joints should be made has never been worked out definitely, but will vary, of course, with the nature of materials and the nature of the sub-soil. A distance of 25 to 30 feet seems to have been arbitrarily adopted in most cases, however, and is on the safe side. As this kind of construction progresses it will probably be discovered that joints can be placed farther apart, possibly up to 50 feet.

Mr. Johnson, who is quoted above, recommends that joints be placed at an angle of 60 degrees with the center line of the road and that alternate joints be made parallel, swinging first one joint 60 degrees in one direction and the succeeding joint 60 degrees in the other. His idea is that placing the joints at an angle will tend to make the irregularity less noticeable as the wheels of vehicles pass over them, while the placing of succeeding joints in opposite directions he believes will tend to reduce any cumulative vibrations.

There are a number of different methods of making joints in these pavements, the most simple but probably the least to be recommended, being that of placing a board in the joint, this board being from 5/8 to 7/8 inch thick and cut to the shape of the finished roadway above and the sub-grade below. This board is held in place by stakes until after the concrete is placed ahead of it, when the stakes are removed, the board being left in place. This kind of a joint is objectionable because of the fact that the board will absorb a large amount of moisture and will expand; if the concrete has not sufficiently contracted to allow this expansion taking a lateral direction the board will expand upward, making a ridge in the road. This board, too, will wear out much faster than the concrete, allowing the traffic to hammer the edges of the concrete, eventually making a joint which will require considerable attention to keep it in shape.

Another form of joint contemplates the use of a similar board, but with the difference that the board is taken out after the concrete has had its initial set and the joint is later filled with some kind of asphaltic preparation.

A much better joint is made by the use of a similar board, to which is tied one or two thicknesses of asphaltic felt. When the joint is placed it is set with the felt toward the completed work and the concrete is then poured in against it. As soon as the next section is started and sufficient concrete poured in against the other side of the board to hold it in place the strings are cut and the board is removed, allowing the concrete to flow up against the felt. This makes a narrow joint, but sufficiently wide for all practical purposes, and is perhaps the best joint in use except the steel protected joint, of which there are several types in use.

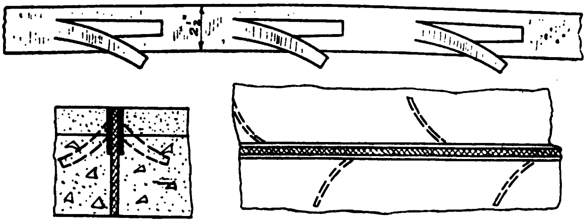
In a few instances creosoted wooden blocks have been used as joint fillers. In some cases these have proven satisfactory, while in other they have not been considered a success. In the city of Davenport, Iowa, they are considered to meet the requirements very well. A creosoted block is ½ inch or 1 inch thick, running the full depth of the pavement and protecting the edges of the concrete. It is stated in its favor that the block has a tendency to broom open and protect the edges on either side, and that it does not seem necessary to put in steel plates to protect the edges.

In making joints it is very necessary that they should be perpendicular to the surface of the slab. If the joint is at an angle, there will be an opportunity, when the concrete expands, for one slab to slide upwards and cause a bump in the road. This will be found to be especially true on roads which are built on a side hill.

Realizing that the edges of the joints of concrete pavements are the weakest part of the pavement, a steel joint protector has been devised. There are several types of these plates described below, but the general type is the steel plate placed at the edge of the concrete at the joint and a projection of some kind extending into the concrete to anchor it. The top of the plate is flush with the surface of the concrete, and the steel of which the plate is composed is of such a nature that its wear will be practically the same as that of the concrete itself.

Roughly speaking, the use of metal plates for joints adds about 5 cents per square yard to the cost of the roadway.

Baker Armor Plate. This joint is made by the R. D. Baker Company, Detroit, Mich., and consists



Baker Armored Joints.

of a 3-16 inch soft steel plate 2½ inches wide and curved to the crown of the road. This plate has shear members cut at regular intervals, these being bent out when the joints are placed, and serving to anchor the joints firmly to the concrete. Two of these armor plates are used at each joint, with one or two sheets of asphalt between them, the felt running to the full depth of the concrete slab.

These joints are assembled in a device known as an installation bar, this being a "T" beam somewhat longer than the width of the roadway, and curved to its crown. The two plates and felt between them are assembled on this bar and locked into position by a locking device which the bar carries. The ends of the installation bar are then placed on the side rails of the roadway in the case of a country road, or auxiliary handles to the bar are allowed to rest on the curb in case of a city pavement.

These plates are made of steel which is tempered in such a way that it will take about the same rate of wear as concrete. It, therefore, continues to protect the edge of the joints during the entire life of the roadway.

Trus-Con Armor Plate. This is a joint protector which has been developed by the Trussed Concrete Steel Company, Youngstown, Ohio, and is made of high-grade open hearth steel plate, and designed to wear with the rest of the pavement, providing at all times a smooth, even surface without rocks or bumps. Each plate is 2½ inches wide and 3-16 inches thick, and is made in lengths to suit. The plates are curved to the contour of the pavement.

Tongues are sheared from the plate at frequent intervals, and these tongues again sheared at the end, the two prongs thus formed being bent in opposite direction, so that the plate is firmly anchored to the concrete.

Two of these bars are clamped together with a layer of asphaltum felt between them, or, if preferred, a steel plate is placed temporarily between these armor plates, and the joint is afterward filled with plastic asphaltum.

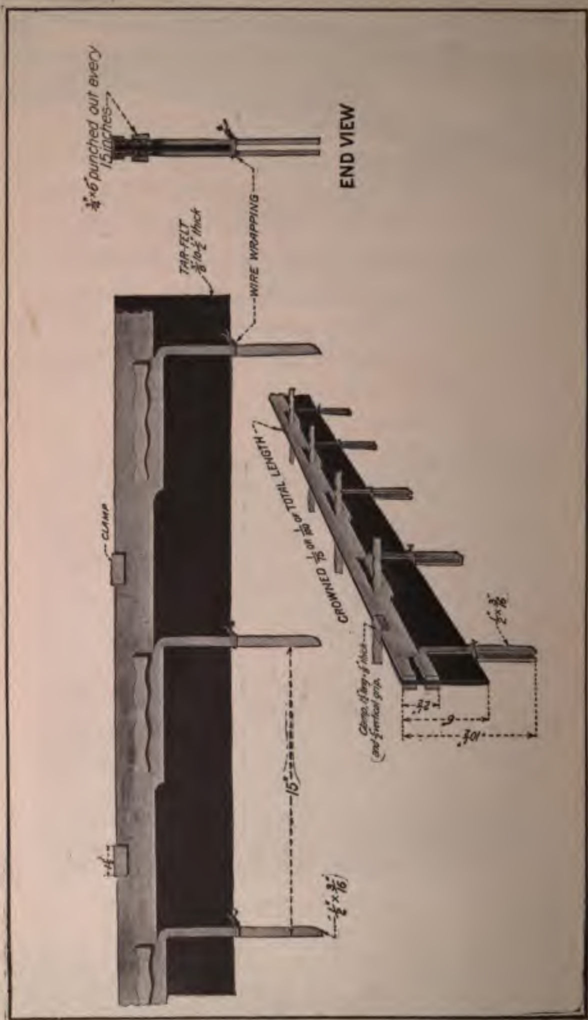
Kahn Armor Plates. These plates are similar to the Trus-Con armor plates with the exception that they are made with a beveled edge extending back into the

Kahn Armor Plate.

concrete at the surface, giving a greater amount of protection and allowing the concrete to have a beveled edge rather than standing up straight. This joint is also made by the Trussed Concrete Steel Company of Youngstown, Ohio.

Anchorite Facing Bar.

Anchorite Facing Bar. This is a bar made from high grade open hearth steel by the Concrete Steel Company of New York. It is 2½ inches wide, 3/16 inch thick and with anchors set on the sides at a distance of



The Moyer Joint.

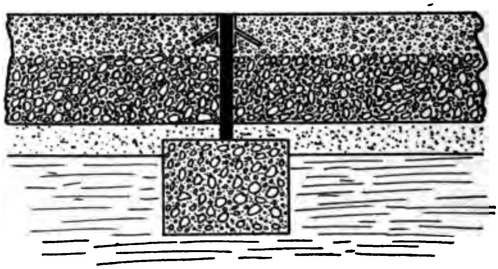
8½ inches apart for anchoring the plate to the concrete. The anchors are riveted to the plate and have diverging prongs which hold them securely in the concrete.

Joint Compounds. Because of the many undesirable features of the poured joint and the fact that there is a great deal of expense and annoyance in heating a small amount of material, several joint compounds which can be used cold in the form of strips have been placed on the market. These are in reality merely premolded strips of asphalt or other similar material and are placed before the concrete is poured and held in place by boards. Joints of this kind are made by the Waring-Underwood Company of Philadelphia, the Bituminous Products Company of Detroit, the Carey Roofing Company of Cincinnati, and others.

Moyer Protected Joint. The distinctive feature of this joint is that it has shear members which can be bent downward on the job and driven into the subgrade until the top of the joint is at grade. These feet help to hold the joints in position while the concrete is being poured. It has also shear members which can be bent outward to anchor the bar to the concrete. The illustration gives the various dimensions and specifications of this bar. It is marketed by Albert Moyer, 200 Fifth avenue, New York.

Longitudinal Joints. There are some engineers who contend that a pavement over 12 feet wide should have a longitudinal joint down the middle. The contention is that a joint of this kind, dividing the pavement into two sections, will reduce the stresses, eliminate longitudinal cracking and will be economical because of the saving of concrete over the thickness which would be required if the entire width of roadway were treated as one slab.

Nine Miles Without Joints. The California Highway Commission has built a considerable amount of concrete road without expansion joints. When examined shortly after construction, one of these roads was found to have developed cracks at distances varying from 6 to 75 feet, the average in the section inspected being about 28 feet. As the concrete will never have any expansion greater than when laid, only contraction



Oshkosh Method of Supporting Joints of Concrete Pavement.

difficulties were anticipated, and it was expected that an oil covering would seal such cracks as might appear.

Support for Joints. The city of Oshkosh, Wis., is trying the experiment of building a support under the joints of concrete pavements. This support consists of a beam of concrete cast in a trench across the street from curb to curb, as shown in the drawing herewith. This beam is about 8 inches wide and 6 inches deep and extends very slightly above the sub-grade so as to insure the compression of the sand under the joint; this, together with the joint filler, is expected to form complete protection against water seepage, which is considered to be the main cause of weakness of pavement joints.

CHAPTER IX.

The Roads of Wayne County, Michigan.

The concrete roads of Wayne County, Michigan—the county in which Detroit is located—have become deservedly famous and are inspected almost daily by parties of road builders from other parts of the country.

There are at least two good reasons why these roads are worthy of special consideration. In the first place, the people who have built them approached the subject of roadmaking with open minds, intent only on getting a road which would best stand the traffic, and without a predisposition to favor any one material above another; the final adoption of concrete means, therefore, that this material proved itself to be, in their best judgment, ahead of any other. In the second place, once having adopted concrete, they exercised the same openmindedness regarding their methods of construction, revising their specifications and practice from year to year as their experience has shown this to be desirable. Their present specifications, as given in Appendix B, probably represent, therefore, the very best practice now in use anywhere.

Mr. Edward N. Hines, a member of the board of road commissioners of Wayne County, has devoted a large amount of time to the development of the concrete road, and has told in a large number of public addresses throughout the country what Wayne County is doing. A good idea of this work can be gained by quoting extensively from these addresses.

"The experience of the Wayne County Road Commission is particularly valuable because we were not committed to concrete at the outset," said Mr. Hines before the Association of American Portland Cement Manufacturers in May, 1912. "Detroit is the heart of the automobile world, and the number of automobiles owned per capita is comparatively very high. This

A Wayne County Road Before Improvement.

new vehicle quickly demonstrated here, as elsewhere, the purely temporary character of many so-called good roads. The automobile picked up the good roads in fine particles and scattered them over the countryside. The modern demands upon highways necessitated new methods and new materials, and we used concrete to meet these demands.

"The Commission, when first organized, followed the accepted practice and started in to build bituminous macadam roads; but after a year's experience in noting the wear upon them, foreseeing a constantly increasing maintenance charge, and harking to the world-wide cry, 'What shall we do to save our macadam roads from the ravages of the automobile?' decided that a change was not only desirable, but necessary, and we set out to find a more permanent and durable material which would approximate in initial cost that of a first-class macadam.

"After thoroughly investigating the subject, studying the experience of near-by smaller towns in the matter of concrete crosswalks, inspecting concrete bridge floors, and noting the general satisfaction concrete was giving in other forms of construction, the grades of

Finishing with Wood Floats.

material used, the light form of construction as applied to cross-walks and bridge floors, we decided that a concrete road would come more nearly realizing the ideal than other forms. The points considered as being in its favor were: Comparatively low first cost; low maintenance cost; freedom from dirt (there being no detritus from a concrete road in itself); its comparative noiselessness; ease of traction for vehicles of all descriptions, and the small crown necessary to get rid of surface water. While we were reasonably sure of our ground, we also felt that in case we scored a partial failure we could use the concrete for foundation purposes.

"Three stretches of road, aggregating two miles, on varying subsoils and with differing specifications, were decided upon.

"These roads are starting on their fourth year of wear, and barring some longitudinal cracks are as good as the day they were built, and practically nothing has been spent on their surface for maintenance. On the basis of three years' thorough trial, I stand committed to the use of concrete for country roads. I also believe concrete to be an ideal form of paving for village and city residence streets and alleys. This is not a statement born of enthusiasm on the spur of the moment, but a cold-blooded dollars and cents view, based on results attained and arrived at after careful consideration of all the facts available and experiences undergone.

"It is to be expected that on our first experimental work we did not achieve perfection. We did not use the same care as we are today exercising in the selection of a clean aggregate or a good mix. Neither were we so careful about striking off and finishing the surface.

I believe I am safe in saying that the concrete roads we are building today are 25 per cent better than our first efforts. We have abandoned entirely the construction of two-course roads built of crushed cobblestone, because of the difficulty of securing a suitable supply of properly graded material of this character. Crushed stone also contains a greater percentage of voids to be filled, and we have standardized on the single course road.

"Any community that wants a good road, a road that is cheaper for even a short time under fairly heavy traffic than any other good road, a road that is inexpensively maintained, a road that is sanitary and dustless, a road that is not slippery, a road that affords good traction for any type of vehicle three hundred and sixty-five days in the year, a road that in the long run, say ten, fifteen, twenty years, and longer, is the cheapest of all good roads, should investigate the merits of concrete.

"The results we have obtained can be secured any-

Method of Mixing and Delivering.

where if strict attention is paid to detail, care used in the selection of good clean stone and sand, and the proper proportion of a standard brand of Portland cement used, coupled with good mixing and care in finishing the surface so it will not be full of depressions. It will not pay to stint the amount of cement used if good results are expected, and there must be adequate, intelligent, and honest supervision."

The following winter Mr. Hines spoke before the Pittsburgh Convention of the American Concrete Institute, from which address we quote:

"With four years' experience as a guide, we have demonstrated in Wayne County that a well-built concrete road is a practical form of construction which merits and will receive a more extensive adoption. Every test to which our work has been subjected only emphasizes its strong characteristics. The points considered are, initial cost, ultimate cost (which includes maintenance), sanitation and freedom from dust, good traction for all types of vehicles, smoothness and ease of construction.

"The initial cost of a good concrete road is little, if any, greater than that of a first-class bituminous macadam road. One of the greatest fallacies indulged in by communities starting to improve their highways, is that cheapness in cost of original construction of roads means economy and that the highway official who can build the greatest area of roads at the least outlay per square yard, is working for the community's best interest.

"On one of the main highways out of Detroit, Grand River Road, the first two miles is tar macadam. If someone had offered to build this road absolutely

Striking Off the Surface.

without one penny's cost to Wayne County, stipulating only that we should maintain it in a fairly average condition, at the end of eight years we would have been money ahead by rejecting the offer and building it of concrete under our present specifications. Of course, six years ago, when we built this road, we did not possess this knowledge, but our experience was one of the reasons for abandoning the construction of this type of road and turning to concrete. When it comes to annual cost, the concrete road stands pre-eminent. With over sixty miles of concrete road in Wayne County, some of it in its fourth year, we have spent less than $300 on its surface for maintenance, and this is what makes this type of road the cheapest of all good roads.

"Woodward Avenue Road, now in its fourth year, shows little or no signs of wear and it is not built nearly so well as our latest constructed concrete roads. A conservative estimate of traffic on this road shows that over 1,300,000 vehicles (more traffic than would go over an ordinary country road in twenty years) have passed a given point, without the development of ruts, holes or bumps and with the expenditure of next to nothing for surface maintenance. On this same road, Woodward Avenue, adjoining our concrete at the 8-mile road, which is the Wayne and Oakland County line, Royal Oak Township this year built two miles of asphalt macadam at a cost of well over $1.00 per square yard. The first mile was opened for traffic August 17. On November 30 I went over this mile and counted 137 holes from one foot up to four, five and six square feet. Fifteen men, a steam roller and a couple of teams were at work patching and repairing and the road is not four months old.

"Whenever men interested in highway construction get together they talk maintenance most emphatically. While not belittling the principle of maintaining a road after it is built, it seems to me, with Wayne County's experience, it would pay other communities to adopt a form of construction on which it is not necessary to expend from $800 to $1,300 a mile yearly to keep it in fairly usable condition. Our concrete roads are sanitary, as there is no detritus from the road itself; there are few cracks and joints to hold dirt and animal droppings, and there is no dust. The drier the weather the less dirt on them, as vehicles do not track mud from unimproved cross-roads in dry weather. What little dirt is tracked on is immediately blown off or washed off by the first rain.

"Our concrete roads have a gritty surface and are not slippery in any kind of weather, affording good traction for all kinds of vehicles. Horses find good footing on them and automobiles do not skid in wet weather.

"It is not necessary to build concrete roads with any great amount of crown, and the tendency to drive in one track, so apparent on macadam roads by the formation of ruts, is eliminated, as the driver of a vehicle can sit comfortably in his seat, no matter on what part of the road he may be driving. Neither can a horse pick out the beaten track as on a gravel or macadam road. A crown of 1/4 inch to the foot disposes of the surface water and tends to distribute traffic over the entire surface of the road.

"With all the other good points in its favor, concrete can be handled with comparative ease, and providing the work is carried on under skilled supervision, can be laid with a working force of relatively unskilled labor. It must be borne in mind, however, that the addition of a little cement to a quantity of stone and sand does not make concrete. There is no material which will respond so quickly to a little care, and if proper attention is given to the detail of mixing and curing, so well repay you in quality and permanence. With the foregoing in mind as to why we are continuing to build concrete roads, I am going to take up a little more of your time and tell you how we are building them.

"Drainage and good foundation are necessary for any type of road, and on a concrete road, the greater care that is taken in this respect, the better will be the final result. A well-drained, well-compacted sub-grade will eliminate cracks to a very large degree.

"One of the bad features alleged against concrete roads is the tendency to crack. In order to overcome this tendency, we prepare our sub-grade as carefully as conditions permit, making it flat and rolling it hard

Striking Off.

and firm. Due to temperature changes and the absorption of water, concrete is constantly in motion and the flat sub-grade tends to overcome frictional resistance and thereby prevents longitudinal cracking. On the first concrete road we built, we crowned the sub-grade to conform to the finished crown of the road and used what I term, for want of a better name, an inverted curb. On this road and on the first concrete road built on Michigan Avenue, where practically the whole road is built on a fill, we have developed more cracks than on all subsequent construction. These cracks, however, are well taken care of at a small expense, by the use of a hot refined tar and sand. On our concrete roads it is the repair of these cracks that has made up surface maintenance cost, and with a well drained, well rolled, firm sub-grade, cracks of all kinds are reduced to a minimum and not to be seriously considered.

"We build our roads in 25-foot sections to provide for contraction and expansion, believing it wise to make our lateral cracks beforehand so we can properly protect their edges from chipping and spalling. We are using a metal plate which is a development of previous experiments. This plate is about 3/16 of an inch thick and 3 inches wide, provided with shear members which tie it securely to the concrete base and wearing surface. It is shaped to conform to the crown of the finished road and two thicknesses of three-ply asphalted felt (about ¼-inch) are inserted between the two plates of each joint. By the use of these plates we have practically overcome the wear at the joints, which is the weakest point in the concrete road, besides securing a smooth, even, continuous finish."

Wayne County is poor in good road material and everything has to be imported. The best results have been secured from the use of washed gravel, ranging in size from ¼-inch to 1½-inch, and washed sand from ⅛-inch to nothing. An effort is made to have the material well graded so as to secure a dense concrete. Freedom from loam, clay or other foreign matter is absolutely insisted upon. These people believe in a rich mix, using one part of cement to three parts of stone, with just a little more than enough sand to fill the voids in the stone. They believe that the detail of mixing and curing the concrete have been as great factors in their success as any other feature.

The roads are constructed with a minimum thickness of 7 inches. After the sub-grade is prepared, side rails of 2x7 inch lumber are placed, protected on top by a 2-inch angle iron. The concrete is laid right on the natural subsoil, which is well sprinkled just previous to the placing of the concrete to prevent the water in the concrete being absorbed.

A wet mix is used. No tamping is necessary, although a couple of men work in it with shovels. It is not considered wise or desirable to have the mortar and fine aggregate worked to the top as it is the stone which is wanted to receive the wear. After the concrete is in place, no workman is permitted in any manner to disturb the finished surface by stepping in it or throwing anything on it. A plank trimmed to the curvature of the road and iron bound on the edges is used to give the road its proper shape. Two men saw this plank back and forth over the concrete, resting on the side rails or form board at the sides of the concrete, over which the strike-off rides smoothly. It is handled with sufficient care to eliminate the necessity for any considerable floating by the follow-up men. These follow-up men, or floaters, work on a bridge which rests on the form boards or rails at the side of the road so there is never any contact with the concrete. The final "smoothing up" is done with wooden floats of home manufacture. When the concrete has become sufficiently firm to permit the removal of the side rails, the finishers, to prevent a sharp division line between the concrete and gravel shoulders, pare off the outer edges which are formed next to the rails.

Each day's work is finished up to an expansion joint, and no more than 20 minutes is permitted to elapse between batches during the day. The work of the day is covered with canvas, and the next day the canvas is removed, and to prevent the concrete from drying out too rapidly, it is covered to the depth of about 2 inches with any sand or loose soil that may be available. The concrete is sprinkled continuously for

8 days and roads are not opened for traffic until at least two weeks after the last concrete is put in place.

The trunk roads are built 16 feet wide of concrete and secondary roads 15 feet, with a minimum width of 22 feet over all. These shoulders are usually built of limestone or gravel in two layers of 3 inches each and rolled with a 10-ton roller. This work is not started until the adjacent concrete is at least three weeks old.

"We do all work ourselves under the day labor plan," says Mr. Hines, "and during parts of our busy season employ as many as 1,200 workmen; handle from 900 to 1,000 cars of materials a month and build a mile of road, in the aggregate, every three days. Machinery plays an important part with us, as we do not believe that a man should be set at a task which a machine can do as well or better. Stone, sand and cement are hauled from railroad sidings to the job by steam hauling engines or combination traction engines and rollers; graders, rooter plows and scarifiers are hauled in the same manner, doing the work of from 6 to 8 horses, more efficiently and more rapidly. Each concrete gang uses about 15,000 gallons of water a day, which is pumped from the nearest available source.

"Two-inch pipe, with a tap every 400 feet, is laid along the road under improvement. Gasoline engines furnish the motive power and we have pumped water as far as six miles. Where we can find room along railroad side tracks, we operate a Brown hoist, with a ton bucket for transferring stone and sand to our hauling wagons. Concrete is mixed in a mechanical batch mixer that travels under its own power, and from which a boom projects, capable of being swung in the arc of a semi-circle. Our men are housed and fed in

COST OF CONCRETE ROADS BUILT DURING 1911 IN WAYNE COUNTY, MICHIGAN.

	Eureka Road		Gratiot Road		Van Dyke Road	
	Quantities, etc.	Cost.	Quantities, etc.	Cost.	Quantities, etc.	Cost.
Length	5,280 ft.	....	1,709 ft.	....	5,555 ft.	....
Total width	23 ft.	....	24 ft.	....	23 ft.	....
Width of concrete	12 ft.	....	16 ft.	....	15 ft.	....
Thickness	....	....	7 in.	....	7 in.	....
Mix	1-2-4	....	1-1½-3	....	1-1½-3	....
Teams	....	$ 980.00	....	$ 6,557.03	....	$ 1,983.75
Other labor	....	3,364.15	....	12,996.83	....	4,012.66
Pebbles	2,014 tons	1,657.78	6,697 tons	6,790.21	3,080 tons	3,082.00
Sand	700 tons	684.94	3,283 tons	2,644.09	1,056 tons	895.75
Cement	1,218 bbls.	1,723.97	9,325 bbls.	9,890.16	3,020 bbls.	4,371.86
Coal	60.75 tons	189.45	118 tons	330.20	34 tons	110.58
Expansion joints	....	77.60	....	528.85	....	66.56
Board of men	....	......	....	439.24	....	200.00
Lumber	....	14.31	....	199.60	....	8.37
Water	....	110.14	....	133.33	....	16.75
Advertising, etc.	....	11.47	....	32.02	....	6.71
Oil, etc.	....	48.51	....	137.11	....	....
Insurance	....	49.41	....	107.62	....	39.00
Hardware, etc.	....	27.50	....	121.50	....	112.29
Miscellaneous	....	101.84	....	153.71	....	5.00
Total cost		$9,041.07		*$411,113.38		$14,911.28

*This includes $51.88 for yard and siding.

COST OF CONCRETE ROADS BUILT DURING 1911 IN WAYNE COUNTY, MICHIGAN.

	Michigan Ave. Road		Mt. Elliott Road		Mack Road	
	Quantities, etc.	Cost.	Quantities, etc.	Cost.	Quantities, etc.	Cost.
Length	39,723 ft.		2,400 ft.		1,400 ft.	
Total width	24 ft.				24 ft.	
Width of concrete	18 ft.				15 ft.	
Thickness	7 in.				7 in.	
Mix	1-1½-3				1-1½-3	
Teams		$10,460.35		$ 867.50		$ 48.50
Other labor		32,078.93		1,884.64		382.83
Pebbles	18,850 tons	20,760.37	1,337 tons	1,336.41	639 tons	677.66
Sand	11,855 tons	9,219.59	456 tons	529.60	160 tons	137.02
Cement	29,909 bbls.	36,747.61	1,305 bbls.	1,879.20	519 bbls.	783.69
Coal	305 tons	907.18	17 tons	55.03	2.03 tons	10.50
Expansion joints		2,614.78		29.79		
Board of men				86.92		12.90
Lumber		456.33		3.06		1.53
Water		128.55		7.75		10.00
Advertising, etc		101.94		6.71		4.71
Oil, etc		354.16				
Insurance				18.07		
Hardware, etc		1,177.62		38.14		6.65
Miscellaneous		433.89				
Total cost		†$115,625.30		$6,742.81		$2,075.99

†This includes $88 for yard and siding and $96 for rental of machinery.

camps along the roadside. We have worked out many other small economies, improvements and labor saving devices which tend to keep the quality up and the cost down. All work is specialized; one crew prepares the grade; another gets the materials on the grade, which is done with such nicety as to make it usually unnecessary to haul in extra sand or pebbles to make a properly proportioned batch; another crew handles the concrete; another builds the shoulders, etc. By so doing, the men become more efficient as they become familiar with their tasks and we secure more and better work out of them."

As to the cost of the Wayne County roads, the commissioners are frank in stating that they are trying to build for permanence and are not thinking so much about low first cost. They are not squandering money, however, and averaging the work done, and including all expenses whatsoever, the cost of these roads is about $1.50 per square yard, the average figure quoted elsewhere in this volume. In regard to the matter of cost, Mr. Hines made the following statement before the Western Society of Engineers:

"The question of cost, as I see it, is largely a local one. I think that in the building of the roads too much consideration has been paid to the man who attempts to build the greatest amount of yardage for the least amount of money, forgetting that cost is an annual affair rather than a first affair. We have built concrete roads in Wayne County as low as $1.04 per square yard, figuring in the drainage, the engineering, the culverts, subgrading, and grading,—all those things,—figuring on the concrete yardage only; and we have built them at a cost as high as $1.71. The conditions on a given mile of road are not necessarily the same as on some other mile. We pay $1.00 per ton for washed and screened gravel. The lowest price that we have paid for washed and screened sand is 83 cents per ton. We have paid as high as $1.85 per ton for gravel and $1.55 per ton for sand. We cannot approximate costs under such conditions. We have hauled as short distances as half a mile and as long distances as nine miles. The question of cost is something that must be settled in individual communities. I think our cost has been, on an average, about $1.50 per square yard. I do not think we shall ever be able to build at as low a cost as $1.04 again, and I think, under ordinary conditions, we shall not have to pay as high as $1.71 per square yard. We have an efficient organization and are putting all the money necessary (not with the idea of being wasteful) into making a good road, a durable road, and a road easily and cheaply maintained."

The tables on pages 78 and 79 give figures on a number of the different pieces of road built during 1911. They do not include the cost of drainage.

CHAPTER X.

CONCRETE ROADS NEAR PHILADELPHIA.

The year of 1913 produced some interesting specimens of concrete road construction in the vicinity of Philadelphia. One of these was built by the Pennsylvania State Highway Department after a thorough investigation by experts into the merits of concrete roads in that and other states. The department then decided to adopt concrete for a very important stretch of road, totaling about three miles.

The road to be improved was an old macadam road at one end and telford at the other. When repairs were made the telford repair material soon disappeared in the mud and the road was as bad as ever. The same applied when stone was put on the old macadam road. The road extends from Huntingdon Valley Station on the Philadelphia & Reading Railway to City Line Avenue, in Moreland Township, Montgomery County, Pa. It is a main highway and the principal entrance into Philadelphia through Foxchase and other important farming communities in that district. It is also a feeder to a fine manufacturing section, and consequently receives a great deal of heavy traffic. And another important point that is responsible for a great deal of traffic is the fact that the road is free, while the other principal thoroughfare from the same section into Philadelphia is a toll road, on which the tolls are very high.

These things were all taken into consideration by the Pennsylvania State Highway Department in considering the type of road to be built, as it was realized that a very large percentage of the traffic that was compelled to use the toll road because of the impassable condition of the other main outlet would abandon the toll road for the new free road. The decision was quickly reached that a well-built concrete road was the only type that should be built, and bids were taken at once.

The total length of the road is 14,317 feet, and the total width is 30 feet to limits of right of way line. The concrete road itself is 16 feet wide, with a 7-foot shoulder on each side. Through the cuts there is a 3-foot gutter, as during heavy rains an immense amount of water runs down over the old road. The contract price for the road was $50,718, which is about $3.57 per lineal of 30-foot road, and includes the shoulders, gutters, tile drains, roadways and all bridges and culverts. The total contract price figured on a square yard basis for the length of road and 16-foot width is about $1.99 per square yard, but this does not mean that the concrete road 16 feet wide cost this amount. It must be taken into consideration that from this should be deducted the cost of the excavating beyond the 16-foot concrete roadway, the gutters and 7-foot shoulders on each side of the road for its entire length, and seventeen concrete culverts, all of which were reinforced and some of them in reality small bridges. The unit prices on the road were as follows: Excavation, 65 cents per cubic yard; concrete laid, sprinkled and topped, $1.10 per square yard; 7-foot shoulders, 20 cents per square yard; gutters on both sides, 10 cents per lineal foot. It will be seen, therefore, that the cost of the concrete road compares most favorably with a macadam or bituminous road of any type.

The road is one course in thickness, without reinforcement of any kind, and is of uniform thickness over the entire width. It is worked to a three-inch crown, the sub-base being also rolled to this crown. The mix was 1:2:4 of carefully selected materials, clean and well graded. Gravel was used on part of the road, and crushed stone on the remainder.

The old foundation was used wherever practical as a sub-base, broken stone being used to strengthen mushy spots, all of which were excavated to a safe depth. The contractor kept an engineer with a transit on the work all the time, as the state gave only the ground levels at the beginning of the work. All other details were left entirely to the contractors. The total excavation amounted to about 11,000 cubic yards, while the fills necessitated the use of the total of this excavation and an additional 10,000 yards, which was obtained from a nearby quarry, and was principally strippings.

As soon as the grader had finished a section of the road, the roller crew took it, rolling and rerolling the sub-base with a 10-ton Kelly-Springfield roller. As soon as a soft spot was found which did not pack properly under repeated rolling, a crew with shovels was put to work taking out the spongy clay, sometimes going down several feet. Such holes were then filled up with stone or gravel, the voids being properly filled with sand. This was then rolled to the level and crown of the rest of the sub-base and made a permanent and solid fill. This sub-base was thoroughly soaked as soon as rolled, and was continually wet from the time it was prepared All of this work was done in April, May and June and much bad weather was encountered and the work held back considerably. In fact, there were several periods when not a wagon could be moved on the road for from five to ten days at a time.

All during the previous winter, the contractors had been hauling stone to convenient points along the line where they had decided to locate the mixing plants.

The gravel and stone used in making concrete were well graded, running from ½ to 1¼ inches. The gravel was shipped to the work in carloads, while the crushed stone was secured from the quarry previously referred to. This stone was a bastard granite and was very hard. It was difficult at times to get the mortar to flush up properly. The sand used was a clean washed Delaware river bar sand. It was coarse and sharp, and graded well up to ¼-inch, containing quite a few fine pebbles about ⅛ to ¼-inch. Allentown cement was used, a total of 6,250 barrels being required. No storage facilities, other than the cars in which the cement was shipped, were provided or required. So carefully had the contractors worked out the requirements that it was possible to store the cement in the cars, at the same time receiving a carload a day, unloading and using same, and keeping an emergency car on hand to provide for shortage, and still keeping within the demurrage limit set by the Interstate Commerce Commission and the railroads.

The contractors provided their own water supply system. A duplex steam-driven pump with a capacity of 80 gallons per minute was set up as required at five points along the road. Water was taken from several streams, all branches of Pennypack creek, and an ample supply of water was to be had constantly. The pump had a 3-inch suction inlet, and the main distributing line was 2-inch screw joint pipe. Frequently this line was 3,500 feet in length, which distance was handled easily by the pump. Along this distributing line were ¾-inch Tee outlets every 200 feet, so that water could readily be had along any portion of the work. No tank was used in connection with this system, a relief valve being used instead, and all water passing the relief valve was then permitted to run back to the creek. The line was, therefore, kept constantly full and under a good working pressure. At times four hose lines were in use at one time sprinkling the road, with other lines running to the mixers.

The mixing plant consisted of a ½-yard Ransome mixer, a ½-yard Smith mixer and a ¼-yard Ransome mixer. These mixers were all steam driven, were mounted on trucks, and equipped with power side loaders and automatic tanks. The ¼-yard mixer was used only in mixing concrete for the many culverts which were built, and this size was found to be most economical, whether the culvert was a large or small one.

Horse buggies were used in handling the material from the source of supply to the mixers. These had wide tires of steel, and did not cut up the sub-grade to any extent. Briggs carts were used to take the concrete from the mixer to the place where it was deposited. Three of these were used with each mixer gang, and each took the entire batch of material from the mixer. These carts also had wide steel tires and helped roll the sub-grade.

The edges of the concrete road do not end abruptly, but have a 3-inch bevel, thus affording additional protection in case a steel-tired vehicle pulls off the road proper onto the shoulders on either side. To secure this bevel, a template was made of wood, and the side forms placed against it, being held firmly in place by long iron pins. This was done after the grade was established. Wood side forms were used, and were always well ahead of the concreting gangs. One carpenter and his helper with each concreting gang attended to making and setting all side forms.

The first concrete on the road itself was laid on July 1, and it took exactly two months to lay the total length of concrete. There were 43 working days, which is the good average of 333 lineal feet of 16-foot road per day, or 5,328 square feet of concrete in nine hours' working time.

There were no expansion joints whatever provided for, and it is expected that the concrete will crack every 30 to 40 feet. It was decided to let the joints open naturally and then to treat them at once by filling in the cracks with asphaltum, giving this matter careful attention. This method of procedure was expected to be equally as good if not better than providing artificial joints, in view of the fact that the entire surface of the road was to have a thin surface coat of Tarvia A.

The template used in giving the road the proper 3-inch crown was a 2-inch plank, properly curved to the crown of the road, the face of which was bound with steel, which both protected the template and made it easier to use without it raising. This template was built by the contractors, had side handles on each end, and was easily operated by two men. It was used in the usual way, resting on the side forms, and worked back and forth across the road. This template was adjustable to different crowns.

The bridge used in floating and finishing off, and fixing up any defects left by the template, was of heavy planks, with truss rod reinforcements, giving it ample strength, and permitting the workers on it to be closer to the concrete surface than is usually the case. Usually one man was able to float and finish up, keeping up with the template. The bridge likewise rested on the side forms, and was so constructed that it could readily be moved and placed by one man.

As soon as the initial set of the concrete had taken place, it was well sprinkled, and was kept wet continuously for six days. Frequently four lines of hose were being used in this work. The road was not covered, as it was to be surfaced with Tarvia, as will be described later, and covering the surface would not only have caused delay in construction and completion of the road, but would have deposited foreign matter that would not have yielded readily to sweeping.

As a topping, Tarvia A was used, 0.4 gallon to the square yard being placed. This portion of the work was done by the Barrett Manufacturing Company, who manufacture the topping used. This topping was delivered hot at the road by the distributing machine, which was mounted on an Alco truck chassis. As soon as the Tarvia had been sprinkled on the road, the entire surface was covered with 3/16-inch trap screenings, evenly spread with stiff brooms, and rolled at once with a 5-ton tandem steam roller. The resulting thickness of the topping is about 3/16-inch. It is expected that this will have to be renewed annually, though it is possible that after it wears off the concrete surface of the road will be permitted to take up the wear. This will be determined by actual usage, however. Just prior to sprinkling the road with Tarvia, the entire surface was well swept with stiff brooms, and all foreign matter and dust carefully removed. The machine traveled an average of 350 feet per minute while sprinkling. The topping was not put on until at least fifteen days after the concrete had been placed.

At all approaches and intersecting roads and driveways to the new road, 100 feet of 8-inch telford road was constructed. This was done to clean the wheels of vehicles about to turn on the concrete road, and will assist materially in keeping the road clean. The crossing at the junction of the concrete road with the Second Street pike is of 12-inch concrete with a dip to carry off surplus surface water, and is spread out to a width of 70 feet, thus taking in the entire intersecting square.

About one hundred men were regularly employed on the work. Two concrete gangs were used on the road work, each consisting of 25 men, distributed as follows: Two mixer men and one mixer engineer, two men feeding sand and five feeding gravel or stone to the mixer, four hauling concrete, three placing and distributing concrete, three men on the stone loader, two men on the template, one on the bridge striking off and floating, two men setting forms and one man sprinkling. Then there was a third crew building the concrete culverts, this crew varying in different locations. One engineer attended to the pump, doing his own firing; one engineer operated the loader, and one engineer with helper operated the steam shovel. Two carpenters with the same number of helpers attended to all form work and side forms for the road, repairs, etc.

The four engineers were paid $2.50 and $3.00 per day; steam shovelmen $6.00 per day; cement workers, template men and finisher on the bridge, all $2.00 per day, and common labor $2.00 per day. In addition to these wages, the contractors housed and fed all men employed, making the wages paid considerably above the average road wages.

Other concrete roads have been built in lower Merion township, Montgomery county, just across the Philadelphia county line. Here are located many fine residence boroughs containing the summer houses of the wealthiest people of Philadelphia. This township has for thirty years been recognized as having the finest roads in the country. Those in charge of these roads decided that, although their own roads were good in most cases, the proven low maintenance and repair costs of the concrete road made it desirable for their district.

The road to be replaced, Railroad avenue, had formerly been the roadbed of the main line of the Pennsylvania Railroad Company in the 70's and was later a macadam road. On part of it there is a 7 per cent grade, about 800 feet in length, at the top of which is a bad curve. Traffic is very heavy over this section, and although in past years it was nearly all horse traffic, now it is practically all automobile and delivery truck traffic. The result is that the pneumatic and solid rubber tires simply pulled the road to pieces, and it was necessary to constantly keep repairing it.

It might also be mentioned here that this road, as well as Greenfield avenue, is used daily as a testing track by the Autocar Company, whose plant is but a couple of blocks distant at Ardmore. Hundreds of truck chasses, heavily loaded with boxes of stone to give them weight equivalent to a loaded truck, are driven at high speed over these roads for ten hours a day, six days in the week. The result has been that these roads, after a few weeks' traffic, became covered with ditches and ruts.

They were repaired every few weeks by the township, so that notwithstanding the heavy traffic, they were kept in fair condition, but the expense was very great.

The old macadam road made an excellent foundation and sub-base where it could be used, although the establishing of the new grades required the removal of a great deal of it. The contractors put five teams, 25 men and a 10-ton road roller at work, and in five days the grading was completed. Five hundred feet of the road on the grade mentioned was sided on both sides with vitrified brick to carry of the streams of water that frequently flowed over the old road during heavy rains.

The construction of the road proper was then started, working from the Lancaster pike down the hill. A new Oshkosh steam driven mixer, with a capacity of 10 cubic feet per batch, was put on the work, the contractors having no larger mixer available and to be spared. This mixer was rather small for the amount of work, and the number of men employed could not make the speed that they should had they been able to get the concrete as fast as they could place and finish it. However, they averaged from 200 to 275 lineal feet of road per day of ten hours, which under the circumstances was not bad. Delays were also caused by the failure of cement, sand and gravel to arrive as had been planned.

The contract price for the Railroad avenue section of the road was $1.00 per square yard. This did not include the cement, of which 800 barrels were required.

The road is 18 feet in width, and is laid on a flat sub-base. The concrete is 5 inches thick at the sides, gradually increasing to 7 inches at the center or crown. A 1:2:3 mix was used throughout on this section. The batch remained in the mixer for from 30 to 40 seconds after being dumped in by the side loader. An automatic water gauge admitted water to the batch after it reached the drum. The mix used was an excellent one, and was fairly wet or sloppy. The sub-base was kept well watered before the concrete was laid, the contractors having laid a temporary line of 6-inch pipe along the road from where the mains of the Springfield Water Company had been tapped. The water main was tapped about the middle of the new road, and a meter placed underground, as the water was not furnished free to the contractors. It will not be out of place to add that in this case, water charges form a considerable item in the cost of the road. This is a point which contractors for roads of this kind should carefully investigate when going over prospective work to make up bids.

The coarse aggregate used consisted of gravel and crushed stone that had passed a ¼-inch screen and was retained on a 1¼-inch screen. The sand or fine aggregate was of excellent quality, well graded from fine to coarse, and was clean and sharp. Both coarse and fine aggregate were dumped ahead of the work and mixer, and directly on the rolled sub-base, which minimized the distance to be carried in the barrows preparatory to loading the mixer. The mixer was kept from 25 to 50 feet in advance of the work, and required but about five minutes to move it by hand.

Wooden side forms of 2x5-inch plank, set on edge and held firmly in place by steel pins, were used. On the section of the road where the brick gutter was necessary, a ½-inch joint between the brick and concrete was provided by setting in a plank of that thickness and 5 inches high. This joint was afterward well cleaned out, poured with asphalt and the top covered with sand, making a tight and waterproof joint, and at the same time protecting the sides of the road from wheels when vehicles should pull up at the curb. These side forms were thoroughly wet before putting in, and were usually removed in about four hours. There was no trouble experienced through side forms sticking or damaging the edges of the road when removed.

Owing to the wet mix used, the road was not tamped. Concrete was placed by barrows and spread with rakes. The smoothing and surfacing crew followed immediately after the template was worked over the surface, establishing the crown. The template was heavy, and operated by three men, one at each end working the template forward and back on the side forms, while the third pulled from the middle with a long handle attached to the middle of the template. This crew was able to easily keep up with five men wheeling and dumping concrete and four men spreading.

A bridge having a clear span of 19 feet was used by the smoothing and surfacing crew, which consisted of two men, who worked the surface with wooden hand floats and trowels, filling up or leveling off any deformities left by the template.

Expansion joints were placed at intervals of 25 feet. The edges of the concrete at these joints were protected with Baker soft steel plates rolled to the shape and crown of the road. These plates were slit so that lugs bent back were firmly imbedded in the concrete. The joint between these plates was formed by a 3/16-inch steel plate fastened to the two plates by means of a clamp. Prior to clamping the two plates and the central division plate, the touching sides of all were well oiled with Monogram grease, medium grade. These division plates were pulled after the concrete had set about four hours, and no trouble was experienced in their removal. Immediately after the removal of the division or center plates, wooden plugs were driven in the joints, these plugs being about 2 feet apart and extending clear across the road, which prevented the joints closing while the concrete was setting.

After the initial set had taken place, usually after about four or five hours, the surface was gone over and lightly scored with a stiff broom, and then well covered with sand and sprinkled at once. Sprinkling was accomplished by means of a hose attached to the temporary water line previously mentioned. The surface of the completed road was then kept moist for several days, after which the sand was swept off. There happened to be sufficient light rain in this instance to keep the surface of the concrete wet, so that no more sprinkling was required.

In keeping the mixer supplied, one man was used in carrying cement to the mixer, one man placing cement in the side loader, two men wheeling sand and four men wheeling gravel or stone. On the mixer, there was one engineer and one man operating the discharging spout into the barrows. The side-loader was operated by the man who placed cement in the loader. Labor was paid 20 cents per hour, or $2.00 per day.

As a result of these Lower Merion roads, Mr. Edward Bok, editor of the *Ladies' Home Journal,* decided to build a similar road in front of his residence in Merion, a neighboring suburb. The road is a main thoroughfare carrying very heavy automobile traffic. After considerable difficulty in securing permission from the township commissioner to build a concrete road, Mr.

Bok instructed Mr. E. J. Hedden, of Philadelphia, to prepare plans and specifications for "the best road that could be built, regardless of cost." Work was begun in December of 1913.

The costs of this road will seem high at first glance, but it must be remembered that the construction, etc., differs materially from other roads. Curb and gutter are included, as is also excavation of the old macadam road, the preparation of a new sub-base being made necessary. The concrete is an inch thicker over the entire road than is usually the case. Double reinforcement was used, and the mix was richer than is generally made. The aggregate used was much smaller than that heretofore used, a small mixer was employed, and only a small section was built. But in spite of all the above, the total cost of the road, foundation, curb, gutter and fixing up after work was completed, was but $2.48 per square yard.

When work was started, the old road was taken up over the entire length of the proposed improvement. This grading averaged from 10 inches to a foot. The new sub-base was trimmed and leveled, and rolled thoroughly with an 8-ton Good Roads Machinery Company's road roller. Natural drainage was provided, the sub-base being a good quality of gravel and sand, with considerable stone left from the old road. The road is on a slight hill, connecting with a Filbertine road at the foot, and with water-bound macadam at the uphill end. That section improved with concrete is just 700 feet long, and is 24 feet wide between the curbing, the total area being 16,800 square feet, or 1,867 square yards.

The curbing was set on both sides of the street. It is native stone, dressed on the work. It is but 2 inches thick, and 14 inches deep, 4 inches projecting above the street or gutter, and 4 inches below the bottom of the concrete slab. It is in very short sections, running from 12 to 18 inches in length. No joints were provided where the concrete road and gutter joined the curbing on either side, and the earth was softened up back of the curb. The idea of this is that as the curb is so shallow and light, and the earth soft back of it, when the concrete expands, it will be able to carry this light curb with it, and the same when it contracts. What the result of this theory and innovation will be, will be carefully watched by all interested.

A 1:2:3 mix was used throughout. The large aggregate was clean gravel, all of which passed a ¾-inch screen, and the sand was clean and sharp, being well graded up to ¼ inch, and was the well-known Jersey gravel, as it is called, although the name is misleading. The material was revolved in the mixer a full minute. The mixer used was a Van Duzen half-bag mixer, capable of mixing 50 cubic yards of concrete per day. The mixer worked close to the point where concrete was being laid, and as it was light, was readily moved without the machine being stopped.

The concrete is all one course, laid on a flat subgrade, and is 6 inches thick at the edges with a thickness of 8 inches at the center, making a 2-inch crown. It is reinforced throughout, the method of placing this reinforcement being a feature. Over the entire road was placed No. 14 gauge triangle mesh reinforcement of the American Steel & Wire Company. Across this mesh, and running from curb to curb, was placed No. 8 gauge wire which was joined to the triangle mesh every 4 inches. This reinforcement was then placed about the center of the thickness of the concrete. Five inches of concrete was laid, the reinforcement was put in place, and then the remainder of the concrete was put on. But a few minutes elapsed between the placing of the first concrete and the last, so that that first placed had no time to harden. The reinforcement settled by its own weight about an inch into the concrete it was laid on, so this brought it about to the center of the mass.

The sub-base was thoroughly saturated before any concrete was laid. All water used on the work was furnished from the private water supply system at the Bok home. Baker joints were used, these plates being placed every 25 feet, and making the concrete slabs 24 by 25 feet. The joints are ¼-inch wide, and are filled with elastite.

The crown was formed by working a template over the surface between the curbs. The bridge rested on boards placed on top of the curbing, and extended over the entire street. The surface was floated and finished from this bridge, after which it was roughly scored with a rattan broom to prevent slipping. It was close to the freezing point while this road was being built, and the contractor kept men there all night working by lantern floating the surface and placing concrete slowly. It was very slow setting, but did not freeze.

An average of 100 lineal feet of road was laid every day, and the entire work was completed in just seven days, which included grading, concreting and curbing. As soon as the surface had set sufficiently, it was sprinkled and covered with sand. The entire surface was well sprinkled every morning, and traffic was not allowed on any portion of the road for two weeks after the last concrete was laid.

An average of 25 men were employed on the work. Three men worked on the mixer, two men delivering gravel and one sand to the mixer; three men wheeling away concrete, two tamping, two on the reinforcing, one on the forms, two on the sub-grade smoothing it up where it had been cut, one finishing off, one on the curb, one superintendent, and the remainder working wherever they were needed.

The costs of constructing this road were as follows:

1,400-foot curb, furnished and set at 25c per foot....	$ 350.00
Excavating and preparing sub-base..................	550.00
Concrete work, 1:2:3 mix, including double reinforcement, gutters, Baker plates with elastic filler, at $2.00 per square yard, 1,867 square yards........	3,734.00
Total cost of road..........................	$4,634.00

An analysis of the above costs is interesting. The road cost complete, which includes sub-base preparation, furnishing and setting curbing and sodding, concrete work and contractors' profits, $6.62 per lineal foot for a 24-foot road, which is $34,953.60 per mile. This is no more than has been paid for other types of roads in this state, although the above prices are higher than a good concrete road can be built for, using the standard thickness, standard mix, either single or no reinforcement, and a contraction joint filled with bitumen and sand mixed. It must also be taken into consideration that this was but a short stretch of road, and that the cost of delivering equipment was the same as though it had been a mile or more in length. The grading cost was 29½ cents per square yard, averaging removal of one foot of material, or about 88 cents per cubic yard. The concrete roadway itself, including double reinforcement, protecting plates and filler for the contraction joints, protection while curing, and all other items, such as bridge, template, lumber, etc., cost $2 per square yard. The furnishing and setting of the curb, and sodding over same, costs 25 cents per lineal foot.

A service test roadway including several sections of concrete construction was completed in the fall of 1913 in the vicinity of Philadelphia. The accumulation of data on this road is to be used as a future guide in connection with country road construction near Philadelphia. The road forms a part of the Byberry and Bensalem Turnpike, a direct road to New York.

On account of lack of transportation facilities and the scarcity of labor, the work was carried on with difficulty. The laborers had to be brought from Philadelphia at the contractor's expense. The materials used were shipped to the nearest stations on the Philadelphia & Reading Railway. The average haul from the railroad to the work was 1½ miles.

The roadway comprises 26 different sections, embracing practically all the present-day standard methods of construction and materials. These methods and detailed costs of construction are included in a report to the Director of Public Works by Mr. William H. Connell, Chief of Bureau of Highways and Street Cleaning. The following are the sections of concrete road:

Five-Inch Concrete Pavement with Bituminous Top. The foundation course was originally old waterbound macadam with a telford base.

The surface was graded to within 5½ inches of the finished grade and additional materials was added where required. It was then thoroughly rolled.

A 5-inch concrete base, proportioned 1:3:6, was

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laid upon the prepared subgrade without joints. The concrete was mixed in a portable rapid mixer, and the surface was finished to grade with a template and trowels and swept with a stiff broom when partially set.

A bituminous top of ½ gallon per square yard of Pioneer Road Surface Asphalt was applied at a temperature of 350° and covered with clean trap rock chips passing ⅜-inch screen and rolled with a 6-ton tandem roller.

Cost—	Cost per
Item—	sq. yd.
Preparation of base course	$0.0571
Concrete pavement	0.9500
Bituminous top	0.1261
Trimming shoulders	0.0130
	$1.1462
Concrete pavement per cu. yd	$6.84

Detailed Cost—Preparation of Base Course.

	Cost per
Material—	sq. yd.
Item:	
1½-in. trap rock, 4.73 cu. yds., at $2.312	$0.0205
Labor—	
Item:	
Scarifying	$0.0132
Shaping	0.0234
533.3 sq. yds at	$0.0571

Concrete Pavement—

Materials—	Cost per
Item.	sq. yd.
1½-in. trap rock, 72.75 cu. yds., at $2.312	$0.3154
Sand, 36.4 cu. yds., at $1.8432	0.1258
Forms, etc., 75-ft. B. M., at $8.50	0.0012
Portland cement, 90.75 bbls., at $1.85	0.3148
Labor	0.1928
533.3 sq. yds. at	$0.9500

Bituminous Top—

Materials— Item:	cost per sq. yd.
⅛-in. trap rock, 4.44 cu. yds., at $3.5944	$0.0299
Pioneer road surface asphalt, 2,260 lbs., at $0.012395	0.0525
Labor— Item:	
Sweeping	$0.0045
Heating bituminous materials	0.0108
Applying bituminous materials	0.0081
Chipping	0.0098
Rolling	0.0105
533.3 sq. yds. at	$0.1261

	Costper sq. yd.
Trimming Shoulders..	
Labor—533.3 sq yds. at	$0.0126

Five-Inch Concrete Pavement with Bituminous Top.—The foundation course was originally old water-bound macadam with a telford base. This was removed to a depth of 5½ inches below the finished grade, and where the original surface was below this grade, the surface was loosened and 1½-inch stone and screenings were spread and rolled to raise the surface to the required grade for the laying of the concrete base.

A concrete pavement 5 inches thick, proportioned 1:3:6 and mixed in a No. 2 Ransome concrete mixer with a charging device was laid on the prepared subgrade. The surface of the concrete was finished with a template and trowels and was roughened with a stiff broom. One-quarter-inch transverse contraction joints, at right angles to the roadway, were provided at intervals of 40 feet. For this purpose ¼-inch iron plates were embedded in the concrete and removed as soon as the concrete had hardened. After the concrete was thoroughly set, the joints were filled with Pioneer road surface asphalt.

From station 52+50 to 54+58 a bituminous top of Ugite was applied. After sweeping the surface of the concrete, 1/6 gallon per square yard of Ugite "A" was applied by hand and ⅜ gallon per square yard of Ugite No. 3 was then applied at a temperature of 280° by a pressure distributor. A coating of ¾-inch dry trap rock chips followed. Another application of ¼ gallon per square yard of Ugite No. 3 was then applied at a temperature of 280° by a pressure distributor, which in turn was covered with torpedo sand and rolled with a 12-ton 3-wheel roller.

From station 54+58 to 57+17 a bituminous top of Tarvia was applied. After sweeping the surface of the concrete, ¼ gallon per square yard of Tarvia "B" was applied cold, after which ⅜ gallon per square yard of Tarvia "A" was then applied at a temperature of 250° with a pressure distributor and covered with torpedo sand.

From station 57+17 to 59+50, a bituminous top of Texaco asphalt was applied. After sweeping the surface of the concrete, ⅛ gallon per square yard of Texaco asphalt cut back with naphtha was applied by hand, after which 6/10 gallon per square yard of Texaco Asphalt, 55 penetration, was applied by hand at a temperature of 450° and covered with clean trap rock chips passing ¾-inch screen and rolled with a 12-ton 3-wheel roller.

Cost— Item.	Cost per sq. yd.
Foundation course	$0.0816
Concrete pavement	0.7464
Shoulders	0.0594
Bituminous top, Ugite	0.1814
Bituminous top, Tarvia	0.1215

Bituminous top, Texaco........................ 0.1632
Foundation course, concrete pavement and bituminous top, Ugite 1.0094
Foundation course, concrete pavement and bituminous top, Tarvia........................ 0.9495
Foundation course, concrete pavement and bituminous top, Texaco 0.9912

Detailed Cost, Foundation Course— Cost per
Materials— sq. yd.
1½-in. limestone, 31.1 cu. yds., at $2.125..........$0.0523
Labor—
Item:
Scarifying $0.0071
Shaping 0.0171
Spreading stone 0.0051

1,263.1 sq. yds. at...........................$0.0816

Concrete Pavement—
Materials— Cost per
Item: sq. yd.
Crushed pebbles, 170.3 cu. yds., at $1.8125........$0.2444
Sand, 84.3 cu. yds., at $1.885.................... 0.1258
Portland cement, 176 bbls., at $1.30.............. 0.1812
Lumber, 150 ft. B. M., at $28.00.................. 0.0033
Labor 0.1917

1,263.1 sq. yds. at...........................$0.7464

Shoulders— Cost per
Materials— sq. yd.
Cinders, 5 tons, at $1.25.........................$0.0049
Labor 0.0545

1,263.1 sq. yds. at...........................$0.0594

Bituminous Top, Ugite, Station 52+50 to 54+58—
Materials— Cost per
Item: sq. yd.
Ugite "A," 75 gals. at $0.07......................$0.0134
Ugite No. 3, 250 gals., at $0.08.................. 0.0512
¾-in. trap rock, 7 tons, at $1.90................. 0.0340
Torpedo sand, 6 tons, at $2.95.................... 0.0422
Labor—
Item:
Hauling $0.0266
Sweeping 0.0019

Applying bituminous materials	0.0064
Spreading chips	0.0057
391 sq. yds. at	$0.1814

Bituminous Top, Tarvia, Station 54 + 58 to 57 + 17—

Materials— Item:	Cost per sq. yd.
Tarvia "B," 91 gals., at $0.07	$0.0139
Tarvia "A," 191 gals. at $0.085	0.0354
Torpedo sand, 9.5 tons, at $2.75	0.0569
Labor— Item:	
Hauling	$0.0085
Sweeping	0.0016
Applying bituminous materials	0.0036
Spreading chips	0.0016
459 sq. yds. at	$0.1215

Bituminous Top, Texaco, Station 57+17 to 59+50—

Materials— Item:	Cost per sq. yd.
Texaco asphalt, 270 gals., at $0.085	$0.0555
Naphtha, 36 gals., at $0.18	0.0157
Trap rock chips, 6 tons, at $2.20	0.0320
Labor— Item:	
Hauling	$0.0072
Sweeping	0.0012
Heating bituminous materials	0.0099
Applying bituminous materials	0.0221
Spreading chips	0.0051
Rolling	0.0145
413 sq. yds. at	$0.1632

Five-Inch Concrete Pavement with Bituminous Top. The foundation course was originally old water-bound macadam with a telford base. This was removed to a depth of 5½ inches below the finished grade, and where the original surface was below this grade the surface was spiked and 1½-inch stone and screenings were spread and rolled to raise the surface to the proper grade.

A concrete base, 5 inches thick, was laid upon the subgrade. This concrete was proportioned 1:3:6 and was mixed by a No. 2 Ransome concrete mixer equipped with a charging device. The surface of the concrete was finished with a template and trowels and was roughened with a stiff broom.

Transverse contraction joints, at right angles to the line of roadway, were provided at intervals of 40 feet. For this purpose two pieces of tar felt paper were embedded in the concrete at each joint and trimmed to the grade of the concrete surface when it was finished.

From station 87+50 to 92, a bituminous top was laid. From station 87+50 to 90, 4/10 gallon per square yard of Dolarway bitumen was applied at a temperature of 270° and covered with torpedo sand.

From station 90 to 90+70, ⅛ gallon per square yard of Bicomac was spread on the surface of the concrete pavement. A mixture of trap rock chips, trap rock dust and Bicomac was then applied and rolled with a hand roller. One-half of this surface was covered with trap rock dust and rolled lightly. The other half was covered with trap rock chips and rolled lightly.

From station 90+70 to 91+35. 4/10 gallon per square yard of asphalt cut back with naphtha was spread upon the surface of the concrete pavement and the naphtha was burned out. Trap rock chips were then spread and rolled into this asphalt coating with a hand roller.

From station 91+35 to 92, ⅛ gallon per square yard of Bicomac was spread upon the surface of the concrete pavement, after which 4/10 gallon per square yard of asphalt was applied at a temperature of 400° and covered with clean trap rock chips passing ¾-inch screen.

Cost— Item:	Cost per sq. yd.
Preparation of foundation course	$0.1680
Concrete pavement	0.8792
Trimming shoulders	0.0391
	$1.0863
Bituminous top Dolarway	0.1689
Bituminous top Bicomac mixing method	0.1203
Bituminous top cut back asphalt fired	0.1057
Bituminous asphalt and Bicomac	0.1004

Detailed Cost Preparation of Foundation Course— Materials:	Cost per sq. yd.
1½-in. limestone, 524 cu. yds., at $2.00	$0.0845
Labor— Item:	
Scarifying	$0.0577
Shaping	0.0012
Spreading Stone	0.0202
Rolling and watering	0.0044
1,240.7 sq. yds. at	$0.1680

Concrete Base—

Materials— Item:	Cost per sq. yd.
Crushed pebbles, 167.6 cu. yds., at $1.8125	$0.2448
Gravel, 82.8 cu. yds., at $1.885	0.1258
Portland cement, 173 bbls. at $1.30	0.1813
Forms, etc., 300 ft., B. M., at $28.00	0.0068
Labor	0.3205
1,240.7 sq. yds. at	$0.8792

Trimming Shoulders— Materials:	Cost per sq. yd.
Cinders, 15 tons at $1.25	$0.0151
Labor	0.0240
1,240.7 sq. yds. at	$0.0391

Bituminous Top Station 87+50 to 90 Dolarway.

Materials— Item:	Cost per sq. yd.
Dolarway bitumen, 200 gallons, at $0.095	$0.0417
Torpedo sand, 7 tons, at $2.75	0.0422
Labor:	
Hauling	$0.0482
Heating bituminous materials	0.0055
Applying bituminous materials	0.0184
Chipping bituminous materials	0.0129
456 sq. yds. at	$0.1689

Bituminous Top Station 90 to 90+90 Bicomac, Mixing Method—

Materials— **Item:**	**Cost per sq. yd.**
Bicomac, 72 gallons, at $0.100	$0.0581
½-inch trap rock, and Trap rock chips, 2½ tons, at $2.20	0.0444
Labor	0.0274
124 sq. yds. at	$0.1299

Bituminous Top Station 99+70 to 91+35 Cut Back Asphalt. Fired—

Materials— **Item:**	**Cost per sq. yd.**
Bicomac, 7 gallons, at $0.10	$0.0061
Cut back asphalt, 58 gallons, at $0.11	0.0555
Trap rock chips, 1½ tons, at $2.20	0.0287
Labor	0.0274
115 sq. yds. at	$0.1177

Bituminous Top Station 91+35 to 92 Asphalt and Bicomac—

Materials— **Item:**	**Cost per sq. yd.**
Bicomac, 46 gallons, at $0.10	$0.0241
Asphalt, 60 gallons, at $0.115	0.0362
Trap rock chips, 2 tons, at $2.20	0.0230
Labor	0.0274
191 sq. yds., at	$0.1107

Five-Inch Hassam Concrete Pavement with Bituminous Top. The foundation course was originally old waterbound macadam with a telford base. This was removed to a depth of 5½ inches below the finished grade and where the original surface was lower than this grade, the surface was loosened and 1½-inch stone and screenings were spread and rolled to raise the surface to the required grade for the laying of the concrete pavement.

Stone was spread upon the foundation course and rolled with a 6-ton tandem roller to a finished depth of

5 inches. From Station 112+50 to 114+85, 2½-inch trap rock was used.

From Station 114+85 to 116, 1½-inch trap rock was used.

From Station 116 to 118, crushed pebbles in size from 1 to 2 inches were used.

Cement grout, proportioned 1:2, was mixed in a Hassam grout mixer and poured on the stone until the grout flushed to the surface. As soon as the grout had settled the road was rolled with a 6-ton tandem roller.

A bituminous top was laid upon the concrete surface. One-fourth gallan per square yard of Ugite No. 3 was applied at a temperature of 250°, by a pressure distributor which was covered with clean trap rock chips passing ½-inch screen and rolled with a 6-ton tandem roller, after which ¼ gallon per square yard of an asphaltic cement was then applied at a temperature of 425° by a pressure distributor and covered with clean trap rock chips passing ½-inch screen and rolled.

Cost—	Cost per
Item:	sq. yd.
Preparation of foundation course	$0.2255
Concrete pavement	0.8919
Bituminous top	0.1331
	$1.2505

Detailed Cost Preparation of Foundation Course—	Cost per
Materials:	sq. yd.
1½-in. limestone, 48 cu. yds., at $2.00	$0.0977
Labor—	
Item:	
Shaping	0.0572
Spreading stone	0.0362
Rolling and watering	0.0344
983.1 sq. yds. at	$0.2255

Grouted Concrete Pavement—

Materials—	Cost per
Item:	sq. yd.
1½-in. trap rock, 28.4 cu. yds., at $2.43	$0.0702
2½-in. trap rock, 58.9 cu. yds., at $2.43	0.1456
Crushed pebbles, 44.9 cu. yds., at $1.8125	0.0911
Sand, 46.7 cu. yds., at $1.74	0.0827
Portland cement, 175 lbs., at $1.30	0.2314
Forms, etc., 275 ft. B. M., at $28.00	0.0078
Labor—	
Item:	
Concrete pavement	0.0991
Grouting	$0.1640
983.1 sq. yds. at	$0.8919

Bituminous Top—

Materials—	Cost per
Item:	sq. yd.
Ugite No. 3, 246 gals., at $0.08	$0.0200
Asphaltic cement, 246 gals., at $0.1095	0.0274
Trap Rock chips, 20 tons, at $2.20	0.0447
Labor—	
Item:	
Sweeping	0.0059
Heating bituminous materials	0.0115
Applying bituminous materials	0.0063
Spreading chips	0.0097
Rolling	0.0076
983.1 sq. yds. at	$0.1331

CHAPTER XI.

Experimental Roads Built by the United States Office of Public Roads.

The United States Office of Public Roads has conducted or assisted in several experimental concrete roads, in which the effect of mixing oil with the concrete, and of treating the surface with various bitumens, have been especially investigated. Since 1911, money has annually been appropriated for constructing experimental roads; prior to this date no funds were available, but the office collaborated with various institutions and communities which bore the expense.

The first of these experimental roads was built in 1909 in cooperation with Cornell University. Two sections of concrete road, one 530 feet long and one 35 feet long, were built. Each consisted of a foundation course of crushed limestone and a wearing course of 4-inch concrete. The longer section was of a 1:2:5 concrete of cement, sand and crushed limestone; the shorter of a 1:2:6 concrete of cement, sand and cinders. All the concrete was mixed in a stationary batch mixer, hauled about 300 feet in a dump wagon, shoveled into place and leveled with rakes. It was then hand tamped and rolled with a hand roller. The work was done in the late fall and the concrete was covered with leaves to prevent its freezing. These were removed after 15 days.

To one section of the road, 30 feet in length, an oil-asphalt, having a penetration of 16.8 millimeters at 25 degrees centigrade, was applied at a temperature of 300 degrees Fahrenheit, at the rate of 1 gallon per square yard. This asphalt did not adhere well to the surface and most of it was worn away by spring. During the next summer, sections were treated with a refined semi-asphaltic oil, an oil asphalt, a refined coal tar and a refined water-gas tar. None of these coatings wore satisfactorily under a rather heavy automobile traffic and a considerable amount of country traffic. Since then, the surface has been annually treated with a bitumen.

At the present time the concrete road does not present as good an appearance as is now obtained by modern approved methods but has proved serviceable and does not show excessive wear. The cinder concrete is smoother but has worn down about ½ inch more than the limestone concrete.

During the next two years, experimental roads were built in several places in which oil-cement concrete was used. The same general methods were used on all these roads. To concrete composed of a 1:2:4 mixture of cement, sand and crushed rock oil was added to the amount of from 10 to 15 per cent by weight of the cement. This was spread on the surface of the road and tamped by hand.

The results obtained were somewhat variable. In one case, no expansion joints were provided and no headers were placed across the road at the end of the days work. This resulted in a sloping joint which has worn poorly. In another case, the work was in the floors of two small bridges. This concrete was rein-

Building the Chevy Chase Experimental Road.

forced with chicken wire and has worn well, showing no sign of cracks.

On another road, the oil-cement concrete, after being placed as above, was covered with a mortar in the proportion of 2 bags of cement, 2½ cubic feet of sand, 7½ cubic feet of trap rock screenings and 8 quarts of oil, which was spread to the depth of ½ inch and floated. In this section 173 feet long, only one expansion joint was set. This consisted of 2 courses of wood blocks 3 inches in width and 4 inches in depth laid on a sand cushion. The joints between the block and the concrete were filled with a native fluxed asphalt. The expansion joint is now in perfect condition and has protected the edges of the concrete well.

This pavement was later covered with three different types of bitumens; a refined coal tar, an oil asphalt and a tar-asphalt, which were applied to different sections of the road and covered with sand or stone chips. A year later some few bare spots were worn in the first, the second was almost all gone and the third was half gone. The surface was then cleaned off and a refined coal tar applied to half and a refined water-gas tar to the other half at the rate of ½ gallon per square yard. The entire section is now in very good condition.

One of the most extensive experiments of the office has been on the Kensington or Chevy Chase road just out of Washington, D. C. The concrete section of this road is 3,950 feet long and 20½ feet wide, built on the west side of a double track street car line. The accompanying table shows the type of pavement, lengths, kind of aggregate, and surfacing of the different sections:

Table I—Length and Composition of Various Sections of Experimental Pavement—Kensington Road.

Kind of pavement	Length	Aggregate	Surfacing
Cement concrete	250	Gravel	Tarvia A
	250	Gravel	Ugite No. 3
	250	Limestone	Special Bermudez Road Asphalt
	125	Limestone	Ugite 1C and Bermudez Asphalt Compound
	125	Gravel	B. A. P. emulsion and Bermudez Road Asphalt
	200	Gravel	Ugite 1C and Texaco J
	50	Gravel	Crude water-gas tar
Oil-cement concrete	150	Limestone	Tarvia A
	150	Limestone	Ugite No. 3
	150	Gravel	Special Bermudez Road Asphalt
	150	Gravel	Texaco Road Asphalt
	260	Gravel	None
Cement concrete....	425	Gravel	None
Cement concrete....	465	Limestone	None
Oil-cement concrete..	210	Limestone	None
Cement concrete....	240	Limestone	None
Cement concrete....	250	Trap rock	None
Oil-cement concrete..	250	Trap rock	None

All work was done by a contracting company with much previous paving experience, according to plans and specifications from the Office of Public Roads. The work was well done, but no effort was made for unusual finish, and the road should be representative of what might be expected from a good contractor.

In the cement concrete the materials were mixed in the proportions of 1 part of cement, 1¾ parts of sand, 3 parts of coarse aggregate, ranging from 1½ to ¼ inch in size, and enough water to form a concrete of "mushy" consistency. For the oil-cement concrete, a residual petroleum oil was added at the rate of 5 pints of oil per bag of cement. All the concrete was mixed in a street paving mixer equipped with a rotary distributing device which deposited the concrete in place on the subgrade. The concrete was deposited to a depth of slightly more than 6 inches, struck off with a strike board and floated with a wooden float from a bridge. No expansion joints were built, excepting such construction joints as were necessary at the end of each day's work. These were made by setting a header perpendicular to the subgrade and at an angle of 80 degrees with the center line of the road. Brass plugs were embedded in the concrete just before the final floating, in 2 rows 5 feet from the edges of the pavement; one row with a 10-foot spacing and the other with a 50-foot spacing.

The concrete was protected while setting, first by a paraffined canvas and later with a 2-inch layer of earth, which was sprinkled for 10 days. When the concrete began to dry out transverse cracks appeared. By the time the concrete had thoroughly dried out, the cracks were an average distance of about 75 feet apart. A few more cracks appeared during the next winter, since which time none have developed. At the present time the average length between cracks is 43 feet for gravel concrete and 121 feet for crushed stone concrete. The shortest distance is 15 feet in gravel concrete; the longest is 220 feet in a crushed stone section. Measurements have been taken from time to time between the brass plugs and indicate that the concrete changes in length with a change of temperature in an amount quite near that to be expected from applying the factor for the coefficient of expansion of concrete, allowing for friction on the subgrade. The width of cracks varies with the temperature, from 1/16 to 1/8 inch in width as a rule, with the largest 1/4 inch at the ends of the longest uncracked section.

The different bitumens were applied hot to the surface of the sections treated by means of a hand distributor at the rate of 1/2 gallon per square yard, after which a layer of stone chips or 3/8-inch gravel was spread over the surface and rolled with a 5-ton tandem roller. Two sections were treated with a paint coat of bitumen before the surface coat, fluxed asphalt in this case, was applied.

The different bitumens have worn and adhered in varying degrees. Those treated with a refined water-gas tar are in good condition; those in which a refined coal-tar was used are in fair condition with numerous small bare spots, while those treated with fluxed native asphalt and oil asphalt are in generally good condition except where the traffic is heaviest, where it has not adhered well. One section was treated with crude water-gas tar at the rate of 1/10 gallon per square yard. This was not sufficient to form a mat, but colored the concrete a deep brown, obviating the glare due to the sun on a white concrete pavement.

The conclusions reached by the office of public roads from the results of the experiments so far conducted are expressed by Mr. J. T. Voshell, senior highway engineer, as follows:

"The surface of the road should be smooth and uniform and to obtain this in a most practical manner rather wet concrete should be used. The coarse aggregate should be relatively small, preferably one in which all of the particles will pass a 1¼-inch screen. The concrete should be rich in cement in order that the mortar may be sufficiently strong and tough to resist, to a considerable degree, the wear of traffic and to hold the particles of the coarse aggregate in place. Transverse contraction joints should be constructed but expansion joints seem unnecessary. Particular attention should be given to the curing of the concrete by covering it and keeping it wet to insure that the mortar will have the essential qualifications of strength, hardness, and toughness, and in order that sufficient tensile strength may be developed, before initial shrinkage occurs, to prevent cracks from being formed between joints. These conclusions are only qualitative. It is hoped, however, that these experiments may eventually furnish sufficient data to warrant, at least, a few definite quantitative conclusions."

CHAPTER XII.

Cost of Concrete Roads in Illinois.

During the season of 1912 five sections of concrete road were constructed by the Illinois Highway Commission, and cost data obtained in the construction of these roads, together with data obtained in construction of macadam roads, makes it possible to estimate with reasonable accuracy the cost of concrete road construction. The facts as here given are taken from the report of the Commission for 1912.

While the data obtained in the construction of these five sections of concrete road would not be adequate as regards the cost of earth work and the hauling of materials, it is conclusive as regards the kinds of work which are distinctive of the concrete roads; that is, the cost of mixing and placing the concrete and cost of expansion joints and of miscellaneous supplies. The cost of earth work and the cost of hauling materials for concrete roads will not differ from the cost of the same class of work on macadam roads. The table which gives an estimate of the cost of concrete roads is based on the information obtained in the construction of five sections of concrete road, so far as the cost of mixing and placing the concrete and the cost of expansion joints are concerned. But for the remainder of the items which enter into the cost of the concrete roads, such as earth work and hauling materials, the table is based on the data for the construction of macadam roads.

In making this estimate, it is assumed that gravel concrete will be used and that the gravel will cost $1.50 per cubic yard, f. o. b. cars, at destination. The cost of hauling material is taken from a curve worked out by the department from data on hauling crushed limestone. But in making these estimates proper corrections have been made for the difference in weight per cubic yard of the two materials.

It is also assumed that cement costs $1.20 per barrel, f. o. b. cars at destination, and no profits or overhead charges are considered in making up the table.

The following explanation of the manner in which the cost of a square yard of 6-inch concrete roadway is determined will show in general how the table is compiled:

The item "superintendence, watchman and miscellaneous labor" is taken from the actual cost for these items on concrete work done by the State Highway Commission.

The items "shaping road bed" and "trimming shoulders" are taken from a table of actual performances. The data obtained in the construction of the macadam roads also shows the cost of loading material on wagons to be 10.7 cents per cubic yard, and the cost per cubic yard for hauling ½ mile is found from the curve. These two items added together and compensated for the difference in weight between gravel and crushed stone gives the item of loading and hauling materials. The other labor items are determined by the assumptions made as regards the cost of gravel and the cost of cement. The items "expansion joints," "coal, oil and miscellaneous supplies for mixer," "forms and other lumber," and "mixing and placing," are de-

Estimated Cost of One Mile of Concrete Road. Based on Actual Cost of Work Done by the Illinois Highway Commission. 1906-1912.

Width.	Cubic yds. gravel per mile.	Sq. yds. per mile.	Average haul ½ mile. Six inches thick.	Average haul ½ mile. Seven inches thick.	Average haul 1 mile. Six inches thick.	Average haul 1 mile. Seven inches thick.	Average haul 2 miles. Six inches thick.	Average haul 2 miles. Seven inches thick.	Average haul 3 miles. Six inches thick.	Average haul 3 miles. Seven inches thick.
10 ft. conc., 6 ft. mac.	Gravel 1,535 Stone 734	Con. 5,867 Mac. 3,520	$ 7,391	....	$ 7,652	....	$ 8,166	....	$ 8,720	....
12 ft. conc., 4 ft. mac.	Gravel 1,830 Stone 367	Con. 7,040 Mac. 2,347	7,802	....	8,902	....	8,563	....	9,140	....
16 feet....	6 inches 2,200	9,387	9,414	....	9,720	....	10,230	....	10,880	....
	7 inches 2,550	....	....	$10,730	....	$11,080	....	$11,680	....	$12,400
18 feet....	6 inches 2,331	10,591	....	....	10,930	....	11,520	....	12,200	....
	7 inches 2,725	....	....	12,050	....	12,450	....	13,150	....	13,950
20 feet....	6 inches 2,592	11,733	11,768	....	12,150	....	12,780	....	13,550	....
	7 inches 3,025	....	....	13,410	....	13,840	....	14,600	....	15,480
24 feet....	6 inches 3,110	14,080	14,122	....	14,580	....	15,350	....	16,320	....
	7 inches 3,630	....	....	16,060	....	16,600	....	17,530	....	18,570

Note.—Cost of gravel assumed at $1.50 per cubic yard, f. o. b. cars destination. Cost of cement assumed at $1.20 per barrel, f. o. b. cars at destination. These costs do not include contractor's profits.

termined from a table, which gives the cost of the work on the concrete roads constructed during 1912.

Having determined the cost per square yard for the two thicknesses given, and for the four lengths of haul given, the cost per mile for the concrete roadway of varying widths is determined by multiplying the number of square yards in a mile of road of the given width by the cost per square yard. The table also gives the cost of a mile of concrete road 6 inches thick and 10 feet wide, with 3 feet of macadam on each side of the concrete roadway. In computing this cost, the cost of the concrete roadway is determined as before explained, and to that is added one-third of the cost of a mile of 12-foot macadam road. This cost of the macadam, alongside the concrete, is determined on the assumption that it is made two-thirds the thickness of a standard macadam road, and being one-half as wide, will therefore require one-third of the material and labor of a 12-foot macadam road.

In the same manner the cost of a concrete road 12 feet wide, with 2 feet of macadam along each side, is determined with the assumption that the cost of the macadam will be one-sixth the cost of a standard 12-foot macadam road.

The details on the various roads built of concrete during the year are as follows:

Chandlerville-Beardstown Road, Chandlerville Township, Cass County. This consists of a section of concrete road constructed over a particularly sandy piece of road just outside the village of Chandlerville. The work was done very largely by subscriptions and the cost data herewith given is made up on a basis of the day labor price for this subscription work, which i

Costs of Concrete Roads Constructed in Illinois in 1912.

Road.	McLean.	DeKalb.	Spring-field.	Carlin-ville.
Amt. of pavement (sq.yds.)	5,000	7,334	5,594	7,111
Thickness	6 in.	6½ in.	7 in.	6½ in.
Width	45 ft.	12 ft.	18 ft.	16 ft.
Length of haul	⅛ mile	½ mile	⅛ mile	Sand, 1½ mile; stone, ½ mi.
Cost of cement	$1.02-1.06	55 cents	$1.02½	98 cents
Cement used per sq. yd	29 bbl.	.31 bbl.	.29 bbl.	.33 bbl.

Cost of Labor and Supplies.

Superintendence	$ 140.00	$ 200.00	$ 202.00	$ 157.50
Excavation	....	900.02	....	591.73
Shaping roadbed	307.41	69.75	232.44	108.70
Trimming shoulders and side roads	....	72.60	211.38	....
Loading and hauling sand and stone, including re-handling	267.34	596.02	603.50	795.05
Mixing and placing conc.	414.63	746.65	644.25	700.58
Watchman and misc. labor.	110.26	187.07	383.75	131.46
Cost of sand and stone f.o.b.	1.017.63	1,671.00	1,622.01	741.00
Cost of cement f.o.b.	1,547.15	1.250.00	1,551.17	2,307.90
Expansion joints	48.67	160.13	206.74	112.40
Reinforcing steel	....	....	....	100.00
Coal and oil for mixer and miscellaneous supplies.	30.75	32.00	119.19	25.00
Forms and other lumber	35.00	119.77	18.33	31.75
Filling expansion joints next curb	45.18	....	....	....
Carfares for men	....	51.16	....	....
Pay for time of men coming and going	....	136.25	....	....
Total	$3,964.02	$6,194.42	$5,794.76	$5,803.07

Cost per Square Yard for Labor and Supplies.

Superintendence	$0.028	$0.0273	$0.0361	$0.0220
Excavation	....	0.1227	....	0.0840
Shaping roadbed	0.061	0.0095	0.0415	0.0153
Trimming shoulders and side roads	....	0.0099	0.0378	....
Loading and hauling stone and sand, including re-handling	0.053	0.0812	0.1078	0.1120
Mixing and placing conc.	0.083	0.1020	0.1150	0.0986
Watchmen and misc. labor.	0.022	0.0255	0.0682	0.0184
Cost of sand and stone f.o.b.	0.204	0.2280	0.2897	0.1050
Cost of cement f.o.b.	0.309	0.1700	0.2772	0.3246
Expansion joints	0.010	0.0218	0.0369	0.0156
Reinforcing steel	....	....	....	0.0140
Coal and oil for mixer and miscellaneous supplies.	0.006	0.0044	0.0213	0.0034
Forms and other lumber	0.007	0.0163	0.0033	0.0047
Filling expansion joints next curb	0.010	....	....	....
Total	$0.793	$0.8186	$1.0352	$0.8176

many cases was more than the work was worth on account of its intermittent nature.

The pavement constructed is a concrete roadway 16 feet wide and is 6 inches thick, gravel being used for the concrete.

The following table is an itemized statement of the cost of this work:

Amount of pavement laid	1,470 sq. yds.
Thickness of pavement	6 inches
Width of pavement	16 feet
Length of haul for materials	½ mile
Cost of cement per barrel	$1.13 and $1.20
Amount of cement per sq. yd. of pavement	0.31 bbl.

Cost of Labor and Supplies.

Superintendence	$ 50.00
Excavation (donation, value estimated)	71.73
Shaping road bed	29.75
Loading and hauling stone and gravel	173.21
Mixing and placing concrete	155.08
Cost of sand and stone	370.85
Cost of cement	553.03
Total	$1,403.65

Cost Per Square Yard for Labor and Supplies.

Superintendence	$0.034
Excavation (donation, value estimated)	.048
Shaping road bed	.020
Loading and hauling stone and gravel	.118
Mixing and placing concrete	.105
Cost of stone and gravel	.257
Cost of cement	.378
Total	$0.960

Sycamore-De Kalb Road, De Kalb Township, De Kalb County. The country is fairly level, and only a small amount of earth work was necessary. The soil is a black loam clay, and the road was well drained. The concrete roadway was made 12 feet wide and 6½ inches thick, with macadam shoulders 2 feet wide on each side of the concrete roadway. The concrete was made of gravel and sand which was purchased in the market, and the cost of the entire improvement was paid from the regular road and bridge fund.

A part of this road was reinforced with ½-inch square twisted 10-foot bars placed crosswise of the pavement, and a part of the road was reinforced with No. 26 A wire mesh made by the American Steel & Wire Company. The mesh is made up of No. 6 wire with 2-inch mesh, and was in strips 34 inches wide, which were laid crosswise of the road, overlapping about 2 inches.

Beginning with the section ending at station 27+45 and continuing to the section ending at station 11+65, the reinforced sections alternate with plain concrete sections as follows:

The sections are numbered at the edge near the expansion joint and each section is the part of the pavement between two expansion joints. The various sections follow each other in the following order and are numbered as here given:

No. 1. Reinforced crosswise with ½-inch bars 2 feet center to center, 12 sections.

No. 2. Reinforced crosswise with ½-inch bars 4 feet center to center, 12 sections.

No. 3. Plain concrete, 12 sections.

No. 4. Reinforced with No. 26 A wire mesh, 4 sections.

The mesh reinforcement cost $1.84 per square of 100 square feet. The bar reinforcement cost 2 cents per pound, f. o. b. Chicago Heights, or 16.8 cents per bar 10 feet long at De Kalb.

The following table is an itemized statement of the cost of this work:

Amount of pavement laid	7,334 sq. yds.
Thickness of pavement	6½ inches
Width of pavement	12 feet
Length of haul for materials	½ mile
Cost of cement per barrel	$0.55
Amount of cement per sq. yd. of pavement	0.31 bbl.

Cost of Labor and Supplies.

Superintendence	$ 200.00
Excavation	900.02
Shaping road bed	69.75
Trimming shoulders and side roads	72.60
Loading and hauling sand and stone, including re-handling	596.02
Mixing and placing concrete	746.65
Watchman and miscellaneous labor	187.07
Cost of sand and stone f. o. b. DeKalb	1,671.00
Cost of cement f. o. b. DeKalb	1,250.00
Expansion joints	160.13
Reinforcing steel (bars, $294.00; mesh, $42.93)	336.93
Coal and oil for mixer and miscellaneous supplies	32.00
Forms and other lumber	119.77
Car fares for men	51.16
Pay for time of men coming and going	138.25
Total	$6,531.35

Cost Per Square Yard for Labor and Supplies.

Superintendence	$0.0273
Excavation	.1227
Shaping road bed	.0095
Trimming shoulders and side roads	.0099
Loading and hauling stone and sand, including re-handling	.0812
Mixing and placing concrete	.1020
Watchman and miscellaneous labor	.0255
Cost of sand and stone f. o. b. DeKalb	.2280
Cost of cement f. o. b. DeKalb	.1700
Expansion joints (materials only)	.0218
Coal and oil for mixer and miscellaneous supplies	.0044
Forms and other lumber	.0163
Total	$0.8186

Peoria Road, Springfield Township, Sangamon County. The soil at the north end is black loam, and farther along clay and sandy soils are encountered. The road leads through rolling country, and a considerable amount of excavation was found to be desirable.

The construction work began during the fall of 1912, and about one-half mile of pavement was laid. The roadway is gravel concrete 18 feet wide, 8 inches thick at the middle and 6 inches thick at the edge. On the section completed, armored expansion joints were used, but on the section to be built in 1913, it is planned to use creosoted block expansion and plain expansion joints filled with asphalt pitch.

The following table of costs applies to the work which was completed in the fall of 1912. A considerable amount of material was on hand at the close of the season, to be carried over and used in 1913:

Amount of pavement laid	5,594	sq. yds.
Thickness of pavement	7	inches
Width of pavement	18	feet
Length of haul for materials	⅛	mile
Cost of cement per barrel	$1.02½	
Amt. of cement used per sq. yd. of pavement	0.29	

Cost of Labor and Supplies.

Superintendence	$ 202.00
Shaping road bed	232.44
Trimming shoulders and side roads	211.38
Loading and hauling sand and stone, including re-handling	603.50
Mixing and placing concrete	644.25
Watchman and miscellaneous labor	383.75
Cost of sand and stone f. o. b. Springfield	1,622.01
Cost of cement f. o. b. Springfield	1,551.17
Expansion joints	206.74
Coal and oil for mixer and miscellaneous supplies	119.19
Forms and other lumber	18.33
Total	$5,794.76

Cost Per Square Yard for Labor and Supplies.

Superintendence	$0.0361
Shaping road bed	.0415
Trimming shoulders and side roads	.0378
Loading and hauling sand and stone, including re-handling	.1078

Mixing and placing concrete	.1150
Watchman and miscellaneous labor	.0686
Cost of sand and stone	.2897
Cost of cement	.2772
Expansion joints	.0369
Coal and oil for mixer and miscellaneous supplies	.0213
Forms and other lumber	.0033
Total	$1.0352

Town Square, Mt. Hope Township, McLean County. In 1907 a macadam road was constructed in the village of McLean extending from the town limits up to the town square, the town square itself not being improved. This town square consists of a triangular park surrounded by a roadway, along which are the principal business houses of the village. The improvement consists of a concrete roadway 45 feet wide, with a total area of 5,000 square yards. The concrete was made 6 inches thick and was constructed from gravel, to which was added a small amount of Joliet crushed stone.

The following table is an itemized statement of the cost of this work:

Amount of pavement laid	5,000 sq. yds.
Thickness of pavement	6 inches
Width of pavement	45 feet
Length of haul for materials	⅛ mile
Cost of cement per barrel	$1.02 and $1.06
Amt. of cement used per sq. yd. of pavement.	0.29 bbl.

Cost of Labor and Supplies.

Superintendence	$ 140.00
Shaping road bed	307.41
Loading and hauling sand and stone, including re-handling	267.34
Mixing and placing concrete	414.63
Watchman and miscellaneous labor	110.26
Cost of sand and stone f. o. b. McLean	1,017.63
Cost of cement f. o. b. McLean	1,547.15
Expansion joints	48.67
Coal and oil for mixer and miscellaneous supplies	30.7

Forms and other lumber	35.00
Filling expansion joints next curbs	45.18
Total	$3,964.02

Cost Per Square Yard for Labor and Supplies.

Superintendence	$0.208
Shaping road bed	.061
Loading and hauling stone and sand, including re-handling	.053
Mixing and placing concrete	.083
Watchman and miscellaneous labor	.022
Cost of sand and stone	.204
Cost of cement	.309
Expansion joints	.010
Coal and oil for mixer, and miscellaneous supplies	.006
Forms and other lumber	.007
Filling expansion joints next curbs	.010
Total	$0.793

Burke Lane Road, Carlinville Township, Macoupin County. The soil is a black loam, and the road was fairly level, but was thickly shaded and had been one of the worst roads in the community on that account. It had been filled in places with stone, brick and cinders, making what little excavation had to be done, expensive. The improvement consists of a concrete roadway 16 feet wide and 6½ inches thick. Crushed stone for the concrete was furnished from the Southern Illinois Penitentiary and sand was hauled from a creek west of Carlinville.

From the C. & A. tracks to the culvert at about station 8, the middle of the road was reinforced by ½-inch square twisted bar 6 feet long, running crosswise and placed one foot from center to center. This was made necessary by a newly filled sewer trench under this section of road.

The following table is an itemized statement of the cost of this road:

Amount of pavement laid	7,111 sq. yds.
Thickness of pavement	6½ inches
Width of pavement	16 feet
Length of haul for materials	16 feet
Sand	1½ miles
Stone	1½ miles
Cost of cement per barrel f. o. b. Carlinville	98 cents
Amt. of cement used per sq. yd. of pavement	0.33 bbl.

Cost of Labor and Supplies.

Superintendence	$ 157.50
Excavation	591.73
Shaping road bed	108.70
Loading and hauling sand and stone, including rehandling	795.05
Mixing and placing concrete	700.58
Watchman and miscellaneous labor	131.46
Cost of sand and stone f. o. b. (stone freight only, sand free)	741.00
Cost of cement f. o. b Carlinville	2,307.90
Expansion joints	112.40
Reinforcing steel	100.00
Coal and oil for mixer, and miscellaneous supplies	25.00
Forms and other lumber	31.75
Total	$5,803.07

Cost Per Square Yard for Labor and Supplies.

Superintendence	$0.0220
Excavation	.0840
Shaping road bed	.0153
Loading and hauling stone and sand, including rehandling	.1120
Mixing and placing concrete	.0986
Watchman and miscellaneous labor	.0184
Cost of sand and stone f. o. b. (sand free at pit)	.1050
Cost of cement f. o. b. Carlinville	.3246
Expansion joints	.0156
Reinforcing steel	.0140
Coal and oil for mixer, and miscellaneous supplies	.0034
Forms and other lumber	.0047
Total	$0.8176

On One of the Roads in Milwaukee County.

CHAPTER XIII.

Other Examples of Concrete Roads.

Milwaukee County Roads. Milwaukee county, Wisconsin, started in 1912 on the construction of a comprehensive system of concrete roads under the supervision of Mr. H. J. Kuelling, County Highway Commissioner, who was formerly with the Wisconsin State Highway Commission.

The roads are all of the one-course type, 16 or 18 feet wide, with the exception of about ½ mile, which is 24 feet wide. The 1912 roads had a crowned subgrade with the concrete uniform in thickness, averaging 7 inches. In the 1913 roads the subgrade is flat and the crown is secured by varying the thickness of the concrete in a parabolic curve, the slab being 8 inches thick in the middle and 6 inches thick at the edge, except for one road 7 inches at the middle and 6 at the edge. In 1912 all the concrete work was done by contract, while some grading was done under contract and some by the commissioner by force account. Culverts were made by a gang of men under his direct control. In 1913 about half the roads were built by force account and half by contract, at substantially the same cost.

During 1912 the concrete used was a 1:2:4 mixture of cement, sand and gravel. An effort was made to secure a pit run material which would approximate the correct proportions of sand and gravel without screening, but this was abandoned as giving excess sand and dirty materials. The gravel from the pit was screened through a ¼-inch screen, all below this size being used as sand and all above up to 2½ inches being considered gravel. In some cases the sand and gravel were mixed at the pit; in others, on the job. During 1913 a 1:2:3½ mixture of cement, sand and stone or gravel was used, the proportions being varied a little where the voids in the aggregate were found to be very low. All cement used was tested at the mills by contract and an occasional test was made in the commissioner's laboratory. Nearly all sand and stone was washed and in every case the sand and stone were brought onto the job separately. The sand was graded from ¼ inch down to not more than 3 per cent passing a 100 mesh screen. The coarse aggregate was, in most

COST OF CONCRETE ROADS IN MILWAUK

	Chicago No. 4		Chicago No. 3	
	Cost per sq. yd. paved	Total cost	Cost per sq. yd. paved	Total cost
Contract price (items below excepted	$0.920	$15,206.68	$0.880	$8,138.7
Shoulders	....	....	.012	144.7
Extras	.001	12.96	.010	91.7
Lumber, etc., for surfacing	....	....	....	....
Cement	.449	7,429.76	.440	4,069.4
Gravel and sand f. o. b. unloading point	....	....	....	....
Labor and inspection	.025	403.75	.033	301.1
Steel for joints	.032	530.94	....	....
Felt for joints	.008	132.51	.007	60.5
Sundries	....	5.14	.002	21.1
Workmen's compensation losses and industrial insurance	....	....	....	....
Machinery depreciation	....	....	....	....
Totals	$1.44	$23,721.64	$1.38	$12,797.5
Length paved	8,264.5 ft.		3,329.5 ft.	
Width paved	18 ft.		25 ft.	
Total number of sq. yds	16,529 sq. yds.		9,248.6 sq. yds.	
Average haul of material	⅔ mile		⅔ mile	

cases, graded from 1½ inches to ¼ inch. Cement was furnished to the contractors by the county, delivered on the job, and special care was given to the care of empty cement sacks, the loss amounting to only 1½ per cent of the total number.

The material encountered in grading varied from sand to stiff clay. Grading was done by wheeled or slip scrapers, with tractors drawing plows or graders wherever possible.

Materials were transported to the job in several different ways. On some jobs teams alone were used, on others teams and steam tractors in conjunction, and on one an industrial track was rented. Material was placed on the road in two different ways—the rows of sand and stone close together, with the cement teams driving on the berm; and the sand and stone separated, with the cement teams driving up the center of the

JNTY BUILT BY CONTRACT (1913).

Name of Road							
esville No. 3.		Janesville No. 2		Green Bay		Mukwanago	
t per yd. ed	Total cost	Cost per sq. yd. paved	Total cost	Cost per sq. yd. paved	Total cost	Cost per sq. yd. paved	Total cost
50	$19,595.20	$1.180	$30,512.91	$0.380	$5,969.65	....	$15,037.62
16	268.18	.001	294.17	.048	754.92	....	....
14	241.00	.001	20.00	.057	895.70	....	....
..	....	....	....	....	....	....	99.36
75	8,093.91	.471	12,166.87	.352	5,539.44	.425	5,819.21
..	....	....	....	.285	4,482.14	....	....
28	473.21	.007	178.29	.079	1,238.68	....	....
34	579.51	.035	898.78	.036	566.51	....	600.83
08	142.52	.008	214.60	.009	133.10	....	170.00
..	5.05	.003	63.35	.003	59.09	....	149.98
..	....	....	....	....	....	....	98.81
..	....	....	....	....	....	....	104.48
'3	$29,398.48	$1.72	$44,348.97	$1.25	$19,634.23	....	$22,080.29
619-24 ft.		12,929.2 ft.		7,854.8 ft.		7,711.9 ft.	
7,694.3-18 ft.		18 ft.		18 ft.		16 ft.	
7,039.3 sq. yds.		25,858.4 sq. yds.		15,709.6 sq. yds.		13,710 sq. yds.	
¾ mile		3½ miles		1½ miles		1½ miles	

road. Water was furnished from the city supply, delivered to the job through 2-inch pipes. A small gasoline engine was used for forcing the water through the pipe where necessary.

The following table shows the average crew used on the work during 1913:

Organization of Concrete Mixer Crew, Milwaukee Co., Wis.

Men	Duty	Cost
1	Foreman	$ 5.00
1	Assistant foreman	3.50
1	Mixer engineer	3.50
1	Fireman	2.75
1	Finisher	3.00
3	Wheeling concrete @ $2.67 per day	8.00
2	Handling cement @ $2.50 per day	5.00
3	Handling sand @ $2.50 per day	7.50
8	Handling stone @ $2.50 per day	20.00
2	Forms and joints @ $2.50 per day	5.00
1	Evening and tamping	2.50
1	Covering and sprinkling	2.50
1	Pump man	2.75
1	Water boy (cared for cement sacks)	1.50
1	Watchman	2.25
28	men. Total labor cost per day	$74.75

Average, 500-600 sq. yds. (95-115 cu. yds.) per day.

Although the methods of construction differed somewhat for different roads, the general procedure was the same. Forms were placed as far as possible in advance, usually about 300 feet, in order to avoid any sudden change in the grade. The forms used were 2x6-inch planks with an angle iron facing one edge. These were staked with iron pins and held firmly to line and to grade. Concrete was placed in several different ways. On the section of the Chicago road built in 1912 the pavement ran on both sides of an interurban railway track. This complicated the work, as it was necessary to find storage room for materials on contiguous private property. The mixer also had to be located at such points as could be found convenient and longer hauls of the concrete were made than would otherwise be allowed.

The plant for this job consisted of a Smith ½-yard mixer mounted for end discharge and delivering the concrete into Briggs carts, in which it was conveyed to the point of deposit. The mixer aimed to cover about 1,000 feet to a set-up, making the longest haul

Chain-Belt Mixer on Milwaukee County Roads.

500 feet in each direction. Up to a haul of about 300 feet two of the Briggs carts were used, while on longer hauls a third one was called into requisition. The materials were wheeled to the mixer by wheelbarrows from stock piles near at hand and dumped into an automatic loader.

Six men were employed on wheeling, 3 men on

Another Milwaukee County View.

the carts, 1 man making up and placing joints and 2 men working ahead cleaning up the roadway and placing forms. This gang covered 400 to 450 square yards per day.

The work on the Kilbourn road was also 18 feet wide and the method of concreting was similar to those employed on the Chicago road, the mixing plant being stationary and the concrete being delivered to the work in Briggs ½-yard concrete carts, with a limit of haul of 400 feet. The crew consisted of 8 men wheeling and shoveling, 3 men on the mixer, 4 men spreading and laying, 3 men on the carts, 2 men on joints, 4 men unloading carts, 1 foreman and 1 boy.

The Janesville road was 18 feet wide. Here a different method of construction was employed, the materials being delivered in the middle of the road, thrown directly into the loading hopper of the mixer and in turn discharged by the mixer directly at the point of deposit. For this purpose a Chain Belt mixer was arranged on trucks for end discharge and provided with a swinging steel chute so that it distributed concrete over the entire width of the roadway. Moves of about 5 or 6 feet were made at frequent intervals. The crew on this work consisted of 17 laborers, 1 engineer and 2 foremen.

On the roads built during 1913, the concrete was in all cases brought to place by spouts or by booms; in no case were horse carts used. Concrete was placed with as little handling as possible and was of such a consistency that there was no separation of mortar and stone. As soon as the concrete was in place, it was struck off with an iron-shod board cut to the crown of the road. As small an amount of finishing as possible was done, and the so-called finisher was instructed

COST OF CONCRETE ROADS IN MILWAUKEE COUNTY BUILT BY FORCE ACCOUNT (1913).

	Name of Road							
	Fond du Lac		Port Washington		Blue Mound		Loomis	
	Cost per sq. yd. paved.	Total cost.	Cost per sq. yd. paved.	Total cost. Gravel.	Cost per sq. yd. paved.	Total cost.	Cost per sq. yd. paved.	Total cost.
Shoulders	$0.088	$1,847.43	$0.035	$ 369.82	$0.074	$ 3,394.17	$0.027	$ 754.29
Hauling and labor loading wagons	.326	6,830.88	.271	2,843.95	.428	19,551.28	.601	16,945.30
Coal, oil, etc., for mixer and pump	.026	547.47	....	....	.018	849.34	.035	980.06
Lumber, etc., for surfacing	.013	283.48	....	....	010	434.46	.009	252.51
Cement	.400	8,395.47	.420	4,411.72	.402	18,404.57	.424	11,965.38
Gravel and sand, f. o. b. unload-point	.300	6,310.68	.275	2,889.82	.292	13,385.05	.076	2,137.98
Concrete surface labor	.307	6,449.50	.187	1,969.52	.258	11,775.94	.233	6,581.71
Steel for joints	.036	752.62	.034	352.55	.034	1,589.83	.036	1,007.51
Felt for joints	.008	165.50	.008	81.50	.007	325.38	.009	258.64
Sundries	.014	302.81	.012	121.19	.008	358.27	.003	94.79
Workmen's compensation losses and industrial insurance	.038	783.81	.031	320.55	.038	1,721.73	.036	1,007.31
Machinery repair and depreciation	.040	828.83	.032	338.95	.040	1,820.60	.038	1,065.16
Totals	$1.57	$33,498.78	$1.30	$13,699.55	$1.61	$73,583.62	$1.53	$43,050.64
Length paved	11,805 ft.		5,255 ft.		22,846 ft.		15,861 ft.	
Width paved	16 ft.		18 ft.		18 ft.		16 ft.	
Number sq. yds. (total)	20,798 sq. yds.		10,510 sq. yds.		45,692 sq. yds.		28,197.3 sq. yds.	
Average haul of material	2 miles		1 mile		1½ miles		2 miles	

merely to remove any foreign matter, which in all cases will come to the surface, and to smooth the marks of the strike board, the idea being to leave the aggregate as near the surface as possible and not to work any appreciable extra amount of mortar to the surface.

During extreme heat or rainy weather the fresh concrete is protected with canvas until it has taken its initial set and can be sprinkled. It is then covered with a light layer of earth, approximately 1 inch thick, and sprinkled each day for nearly a week. Traffic was kept off the pavement for at least three weeks, or longer, if the weather was unfavorable for the hardening of the concrete.

Where earth shoulders were built, the work was done by the mixer crew at times when material was lacking or machinery broken. Where gravel shoulders were built, they were not constructed until after the road was thrown open to traffic.

Transverse expansion joints were put in, spaced 25 feet apart in the 1912 work and 35 feet apart in 1913. It was decided to increase the distance to 50 feet on work done in 1914, since the shorter distances have shown no cracks. The expansion joint consists of two Baker dividing plates, having shear members which extend into the concrete and anchor the plate firmly to it. Asphaltic felt 1/4 inch thick and the full depth of the pavement is placed between the plates.

At Winona, Minn. In 1912 Winona County, Minnesota, let contracts for 16 miles of concrete roads, at a cost of $116,000. This price was about $10,000 less than the lowest bid on the same roads in macadam, by the same bidders, and figures out to about $7,250 per mile, although the grading varied to such an extent as to make an average figure of little value. The specifications provide that the sub-grade shall be brought to a firm, unyielding surface where fills are made, by rolling each 6 inches of fill. All soft or spongy spots, vegetable or perishable matter is removed and replaced by the same material as that of which the sub-grade is composed. When heavy clay soil is encountered it is provided that the sub-grade shall be excavated 4 inches below grade and shall be filled with crushed rock or gravel rolled to a thickness of 4 inches.

The concrete roadway proper is laid on the center line of the road to a width of 8 feet and a thickness of 6 inches, with a crown of 1 inch. The concrete is laid in sections 35 feet in length, separated by ⅜-inch expansion joints, these extending through the entire thickness of the slab and being filled after construction with a bituminous filler. The expansion joints are formed by three strips of steel, cut to the size and shape of the cross-section of the road, and with projections at the ends to permit of their removal. After the concrete has set the middle strip is first removed, after which the other strips can readily be taken away.

The surface of the roadway is finished with a wood float, and where the grades exceed 4 per cent the surface is grooved with a grooving tool in both directions, the longitudinal grooves being 10 inches apart and the transverse grooves 3 inches apart. The grooves are ¼-inch wide and ⅜-inch deep.

The specifications provide that the sand shall be graded up to ¼ inch and shall not contain clay or loam in excess of 4 per cent. The gravel provided for is composed of hard, dry pebbles not larger than 1¼ inches nor smaller than ¼ inch.

The materials are put onto the road in the proportions of 1, 2 and 4, the sand and gravel being measured loose in measuring boxes and a sack of cement being considered equal in volume to one cubic foot.

The specifications call for a mixture of such consistency that it will quake slightly when tamped, but not so thin that it cannot be troweled to the required cross section. The mixing is done by a Koehring street paving mixer of the self-tractive type, carrying a swinging boom which covers the entire width of the roadway for the delivery of the concrete. The machine is equipped with an end-loading bucket holding the full capacity of the drum, with a water measuring tank which supplies the proper amount of water to each batch, and a water tank mounted on the frame to supply water for the steam boiler. This machine discharges at the rear and is provided with traction drive for moving it along the roadway so that it may always be located just at the point where concrete is to be placed.

The specifications provide that the contractor shall wet and tamp the sub-grade to a proper form immediately before the concrete is placed and that the concrete shall be placed to full width and thickness of the roadway at one time and well tamped and struck off with a template and floated to the entire cross-section with wood floats.

After the concrete is set, it is covered with about one inch of wet earth and gravel and is kept free from travel for a period of two weeks.

On each side of the concrete roadway is a shoulder of gravel which is rolled to a thickness of 6 inches at the edge of the concrete, 4 inches at a point 4 feet away, and is feathered off to a point 6 feet from the edge of the concrete.

Where it is necessary to carry flood waters over the roadway, especially on side hills, the concrete is placed the full width of the roadway in the form of a "dip," somewhat similar to the old-fashioned "thank-you-ma'am" of the dirt road. This dip has a depression of 6 inches to 10 feet out of grade line, and is given a slight skew to the lower side of the road so as to carry off the water more readily.

The quantity of concrete used is 14.81 cubic yards per 100 feet, or 782 cubic yards per mile.

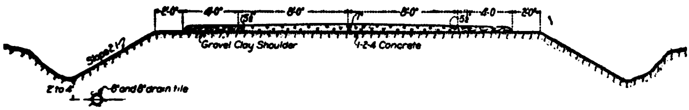
The contract price as given includes all grading, of which there is over 40,000 cubic yards, also culverts and a small amount of concrete and rip-rap retaining walls.

In a paper before the Minnesota Society of Engineers and Surveyors, Mr. O. B. Leland, engineer in charge of the Winona work, stated: "The grading is costing on an average a little over 40 cents a yard. The concrete culverts cost about $50 each for 18-inch, $65 each for 24-inch, $85 for 30-inch, and $105 for 36-inch, placed in the road. The average cost of grading per mile, including culverts, is $1,500. The macadam costs about 25 cents per lineal foot of road, and the concrete 90 cents per lineal foot of road. We are getting 16 miles of good road for $116,000."

Data on an Iowa Road. Cerro Gordo county has the first mile stretch of permanent road built in Iowa. It was built on the worst mile of the road between Mason City and Clear Lake, about midway between the two cities, at a cost of $10,646.72 or $1.124 per square yard. This cost includes almost $1,000 spent for grading the road preparatory to paving.

This mile of concrete road is 16 feet wide with 4-foot gravel shoulders on each side sloping to good side drainage ditches located 10 feet from each edge of the paved portion.

On this work the road was less than two miles from a railroad siding and a good source of sand supply was developed less than a mile from the work on land belonging to the county. Hauling was therefore possible with team and wagon. Water for steam engine, mixing and sprinkling was provided by a gasoline engine driven duplex pump, direct connected to a 2½-inch pipe line about 3,000 feet long. This pipe line was laid on the surface along the fence line at the side of



Cross Section of Concrete Road Near Mason City, Iowa.

the road. It was provided with hose connections and valves at intervals of two hundred feet. These were used for attachment to the mixer, boiler and for sprinkling. The water was pumped from a creek crossing the road near the quarter line, against a gravity head of about 15 feet and a friction head of about 35 feet for maximum length of pipe. Gasoline consumption was about 3 gallons per day of 9 hours. A safety valve at the pump prevented an excess of pressure on the line.

The mixer was a Koehring street mixer loaned by the Iowa Highway Commission. This mixer has been in use two seasons laying concrete roads on the campus of the Iowa State College at Ames. An average of 500 square yards per day of 7-inch pavement is easily made with this outfit and twenty men.

The concrete was made 1 part cement, 2 parts sand and 3½ parts of coarse aggregate, either the gravel or the crushed rock, up to 1½-inch size.

For side forms 2x6-inch lumber was used and held to line and grade by iron stakes driven in the ground. The surface of the sub-grade was carefully leveled just before laying the concrete and was kept well saturated with water. The sub-grade was flat and extra thickness of concrete was obtained at the center by crowning the road 1½ inches in the 16 feet. This made a road 6 inches thick at the edges and 7½ inches thick at the center.

Cost Data on Concrete Road, Cerro Gordo County, 1913.

		Per Sq Yd.
Freight on mixer Ames to Mason City......	$ 30.00	
Freight on mixer Mason City to Ames......	26.64	
Freight on Baker joints..................	53.97	
Engineer Dodds' expenses.................	49.31	
	$160.31	.0170
Misc. teaming, hauling pipe, mixer, etc.....	$ 71.43	.0075
Oil, coal, gas, repairs....................	60.55	.0064
Misc. labor unloading mixer, laying pipe, building culverts, lost time, etc........	176.69	.0187
Lampert Engineering or foreman..........	125.00	.0132
Plant bought $523.48, 20 per cent to job or..	105.00	.0111

Labor

Average organization, wages paid 500 square yards daily.

Men.	Job.	Rate.	Day.	Sq. Yd.
3	Finishing, removing form......	27.5	$ 8.06	.0160
2	Striking off grading conc......	27.5	5.50	.0110
1	Fireman on mixer.............	35.0	3.50	.0070
1	Engineer on mixer............	40.0	4.00	.0080
2	Side forms and joints.........	30.0	6.00	.0120
1	Cement	30.0	3.00	.0060
2	Wheeling, shoveling sand......	27.5	5.50	.0110

3	Wheeling stone 27.5	8.25		.0165
6	Shoveling stone 27.5	16.50		.0330
1	Extra fixing sub grade.........27.5	2.75		.0055
1	Water boy 10.0	1.00		.0020
1	Hose boy 10.0	1.00		.0020
		$65.00		.1300

Grading

Grading about 3,100 cubic yards.			
Wheelscraper and wagon work.....	$497.25		
Loading wagons	60.00		
	$557.25	.18 cu. yd.	.0588
Surfacing	$307.50		.0325

Material

Baker joints and felt..............	$536.40		.0566
Sand, 874 cu. yds. taken from Co. pit:			
Stripping pit	60.00		
Loading	123.50		
Hauling	243.00		
	$372.50	.426 cu. yd.	.0393
Crushed stone, 560.74 cu. yds. at $1.00	$560.74		
Freight	285.09		
Loading	141.45		
Hauling	341.00		
	$1,328.28	2.37 cu. yd.	.1405
Gravel, 855 cu. yds...............	$595.04		
Freight	403.02		
Loading	123.50		
Hauling	493.00		
	$1,614.54	1.89 cu. yd.	.1705
Cement, 2,413 bbls. at $1.56 on cars at Emery	$3,764.28		.4220
Hauling	217.17		
	$3,981.45		1.1240
9,472 sq. yds., Total.............	$10,646.72		$1.124

Note. Transfers helped load material.

This labor account is high because it includes the wages when there were more than twenty-three men around mixer, for when hauling was impossible the shovelers from the cars worked around the mixer also.

Cost of a California Road. On the Huntington Drive, Alhambra, Cal., there were laid in 1913 about 28,280 square yards of concrete road surfaced with asphaltic oil. This road had a uniform thickness of 6 inches and the amounts of the various materials used per square yard was as follows:

Cement, bbls.	0.2104
Screened gravel, cu. yds	0.1316
Sand, cu. yds	0.0622
Water, gals.	7.0
Oil, gals.	0.2562
Screenings, tons	0.0063

The cost to the contractor of constructing the pavement, not including overhead charges, is as follows:

	Per sq. yd.
Materials:	
Lumber, 26,000 ft. B. M	$0.0211
Screened gravel, 3,723 cu. yds	0.0658
Sand, 1,758 cu yds	0.0193
Screenings, 180 tons	0.0054
Water, 7 gals. per sq. yd	0.0005
Total materials	$0.1121
Labor:	
Excavation, 2,997 cu. yds	$0.0507
Shaping 12,645 lin. ft. roadbed 20 ft. wide	0.0515
Hauling 26,000 ft. B. M. lumber	0.0085
Hauling 3,723 cu. yds. screened gravel 6 miles	0.1126
Hauling 1,758 cu. yds. sand 6 miles	0.0314
Hauling 5,951 bbls. cement 1½ miles	0.0204
Hauling, miscellaneous	0.0029
Mixing and placing concrete	0.0739
Hauling and spreading 172.86 bbls. oil	0.0018
Unloading, hauling and spreading screenings	0.0035
Total labor	$0.3572
Total cost materials and labor	$0.4693

The cement cost $1.647 delivered on the job, or $0.347 per square yard. The oil was also furnished by the county at a cost of $0.0084 per square yard.

An Experimental Road in California. An experimental concrete road, 3,000 feet long and 18 feet wide, was constructed in the fall of 1912 between Sacramento and Riverbank, Cal., passing through the Riverbank subdivision of the West Sacramento Company. The company has large holdings in this vicinity, in the development of which the road problem led it to experiment with ten various sections of concrete pavement to determine its applicability to local climatic, traffic and subgrade conditions. The engineers also wished to determine the most economical design. It is believed the comparatively uniform temperatures in California will minimize to a large extent expansion and contraction difficulties. The details as here given are taken from *Engineering Record* of March 8, 1913.

On the western half of the roadway the sub-grade material is a heavy clay loam soil, resembling an adobe. The eastern half of the slab was constructed over an old macadam roadway. The subgrade was excavated and trimmed to the required grade and crown. It was then thoroughly compacted by sprinkling and rolling with an 8-ton roller. All portions of the old macadam road in fill were well tamped. In all cases the subgrade was well moistened just previous to placing the concrete to prevent abstraction of water from the concrete.

All work was given a crown by sloping the surface from the center to each side of the roadway at the rate of ⅓ inch per foot. Local experience with other types of pavement has led to a standardization of this feature. Longitudinally the roadway is practically level.

Four types of expansion joints were experimented with. In the first, lines of oiled surfaces were spaced at 10, 20, 30 and 40-foot intervals squarely and diag-

COMBINATIONS IN VARIOUS SECTIONS OF CALIFORNIA EXPERIMENTAL ROADWAY.

Length in Feet	Thickness in Inches	Mixture	Reinforcement	Surface	Expansion Joint
600	6	1:2:5	None.	Grooved with tampers.	Oiled paper, oiled surface.
200	6	1:2½:6	None.	Sanded.	Oiled surface, ¼-inch spaces filled with bitumen and screenings.
200	6	1:3:6	No. 12 rect. wire mesh.	Concrete surface plain. Roadway surface ⅝-inch bitumen and screenings.	¼-inch spaces filled with bitumen and screenings.
300	6	1:2½:5½	None.	Surface of concrete plain. Surface of roadway ⅝-inch bitumen and screenings.	¼-inch spaces filled with bitumen and screenings.
275	6	1:2½:6	None.	Plain.	Diagonal joints, single thickness tarred paper and oiled surface.
247	4	1:2:4	No. 7 triangular mesh.	Roughened with embossed tampers.	Oiled surface.
250	4	1:2:4½	None.	Broomed.	Easterly 120 feet, one thickness tarred paper, remainder oiled surface.
250	6	1:2:5	None.	Roughened.	Oiled surface.
260	5	1:2½:6	No. 7 triangular.	Broomed.	Double thick tar paper.
270	5	1:2½:5	None.	Roughened with embossed tampers.	⅝-inch spaces at 30 feet protected by iron plate.
217	4	1:2:5¼	No. 12 rect. wire.	Checkered with grooves.	None.

onally across the pavement. Tar-paper joints were laid 10 and 20 feet apart on square and diagonal lines. In another section ¼-inch spaces were filled with bitumen at intervals of 25 and 40 feet on square and diagonal lines, transversely with the pavement. A fourth type consisted of ⅜-inch spaces at 30-foot intervals, squarely across the pavement, with the edges protected by soft steel plates 4 inches wide and held in place by anchor bolts. A section 217 feet long was laid without expansion joints.

Various types of finished surface were used. These included roughening with wire brooms, pitting by an embossed tamper, checkering and grooving with checks 6 inches square, plain concrete, sanding and covering the surface with a $\frac{3}{16}$-inch coat of bitumen and Natomas rock screenings.

Three classes of fine aggregate were used: First, Sacramento River sand, dredged near the site of the work, having very fine, much rounded quartz grains. It contains a considerable proportion of mica flakes, but very little sediment. Second, Yuba River sand, dredged from the Yuba River at Marysville, having medium-sized quartz grains, somewhat rounded. It contains little mica, but small amounts of sediment and small balls of mud. Third, Natomas fine crushed rock, varying from ⅜ inch to dust. It is very sharp and carries so much fine stone dust that it is difficult to determine the percentage by sedimentation.

Tests were made of the three classes of fine aggregate and for comparative purposes strength tests were made on Ottawa sand. Voids were determined by thoroughly compacting 100 cubic centimeters of dry sand, then adding 100 cubic centimeters of water and reading the amount absorbed by the sand. Briquettes were made of standard Ottawa sand and cement, as well as of the materials to be tested. The quantity of water, however, was varied in order to get a mortar in each case as nearly as possible with the same consistency as that made from the standard sand. As compared with the standard sand there was required for the Sacramento River sand nearly double the amount of water, for the Yuba River sand 50 per cent more water and for the Natomas fine crush about the same quantity. Tensile tests were made after seven days. It will be noted that the Natomas fine crush made a considerably stronger mortar than the standard Ottawa sand. In all cases the coarse aggregate was material obtained by crushing the tailings from the gold dredgings in the vicinity of Folsom. The dredgings vary from pebbles the size of an egg to boulders a foot or more in diameter, composed of a hard and tough, altered andesite. As placed on the market the rock is in four sizes: 2½ to 1½ inches, 1½ to ¾ inches, ¾ to ⅜ inch; screenings, ⅜ inch to dust. Only the last three sizes were put into the road concrete. The percentage of voids in the 1½ to ¾-inch size ranged from 46.7 to 48.5 loose; the ¾ to ⅜-inch size ranged from 43.3 to 39.7. By mixing these two sizes in various proportions the voids were reduced to about 40 per cent.

Cost of Owatonna Road. There was completed in 1912 near Owatonna, Minn., a stretch of 1,100 feet of concrete road on the main traveled highway between Owatonna and Albert Lea, a road over which a considerable amount of automobile traffic passes. The concrete is 8 feet wide, 6 inches thick, with 1-inch expansion joints every 50 feet, these expansion joints being filled with pitch. Corrugations to prevent slipping occur at 4-inch intervals.

The road is over a sand hill, most of it in a cut where sand washed badly, making it impossible to preserve any shape to an ordinary road. It is expected that this road, aside from giving much better service, will do away with heavy maintenance charges. The road has little or no crown, but has clay and gravel shoulders on each side sloping down to an edge 3 feet away.

Had it not been for the sand on which this piece of road was built and the necessity of hauling clay for the sides it could have been built for 90 cents per running foot. The actual cost, however, was about $1.03, as shown in the following itemized statement of cost. The item of grading has not been taken into account in these figures.

Labor	$276.00	
Cement	464.76	
Gravel	162.85	
Lumber	33.72	
Total	$936.73	$ 936.73
Deduction for cement	68·76	
Deduction for extra labor	86.25	
	$155.01	$ 155.01
Deducted total		$ 781.72
Building gravel sides cost		350.00
Total cost of road		$1,131.72

Common labor received $2.00 a day, a man and team $4.00; cement was delivered at the work at $1.43 per barrel and gravel delivered at the work at -1.00 per yard.

Roads in Idaho. The following is the report of a

The road here illustrated as under construction is known as the Pacific highway, and is located in Lewis county, Wash.

It is being laid in two courses, the base being of a 1:3:6 mixture with egg gravel, 5 inches thick at the center and 3½ inches at the sides. The surface is a 1:1:2 mixture with pea gravel. The width is 16 feet.

A Koehring street paving mixer is being used.

ypical day's work on concrete roads in Ada county, daho:

'hree men wheeling, two men shoveling gravel for mixer at $2.75 for eight hours	$ 13.75
'wo men wheeling sand, ditto	5.50
ne wheeling cement, one loading cement, ditto	5.50
ne mixer man on loading and tending water	2.75
ne engineer (sub-foreman) and delivery operator	3.00
'hree men setting forms, $2.75 for eight hours	8.25
ne sub-foreman	3.00
ne superintendent	5.00
ngineering and field supervision	25.00
ne water team and man	7.25
05 depreciation on equipment	10.00
ne timekeeper	3.00
Cost of materials—	
,200 square yards crushed gravel and sand at 7 cents.	84.00
1 barrels Red Devil Portland Cement, at $2.60	236.60
gallons gasolene for mixer at 23 cents, oil 15 cents	1.30
Total	$419.90
00 square yards of concrete, 7 inches thick, on crushed gravel well rolled, cost per square yard	$ .70

At Sebewaing, Mich. During the summer of 912, one mile of experimental road was constructed at ebewaing, Michigan, half of which consisted of a con-rete pavement 9 feet 2 inches wide, of an average hickness of 6½ inches, with 3-foot gravel shoulders on ach side, and one-half mile of tar macadam, 9 feet vide with dirt shoulders 5½ feet wide on each side. 'he contract for both stretches of pavement was let to he same firm. The total cost of the one-half mile of oncrete roadway was $3,592 and of the tar macadam 3,753; a first-class concrete pavement in this case ac-ually costing $161 less than first-class tar macadam. 'he road leads to a sugar beet factory and during the all was subjected to heavy traffic. Reports from Sebe-vaing are to the effect that the concrete is in first-class ondition, as good as when laid, whereas the tar ma-adam is commencing to show wear.

Building a Colorado Road with a Smith-Chicago Mixer.

California State Highways. There are several interesting features in connection with the construction of 14 miles of state highway from Healdsburg to Santa Rosa, California. Most of the construction was over old roads with hard surfaces which had to be broken up before they could be graded. The road, 15 feet wide with a 4½-foot shoulder on each side was a 4-inch slab of concrete with an asphaltic oil wearing surface, on a specially prepared and compacted sub-base. After the rough grade had been brought to within 0.1 foot of the exact elevation the grade and line stakes were set. The concrete slab had a crown of 2½ inches, the arc being a parabola. From the edges of the slab the shoulders sloped straight, dropping 4 inches in 4½ feet. Two lines of grade stakes were employed, one on each side of and 9½ feet distant from the center line, making them 2 feet out from the side forms on each side. These 2-foot intervals gave ample room to set and peg the side forms without disturbing the grade stakes. The carpenters notched their levels 2 feet from the ends and with them alone, adjusted the form board both to distance and grade, working from the grade stakes.

The side forms were usually handled by two men at $2.75 per day and two men at $2.50 per day. These could place, line up and fasten about 800 feet on each side, or 1,600 feet of side forms per day at the following costs:

	Cost per day
2 carpenters at $2.75	$ 5.50
2 helpers at $2.50	5.00
*1600 feet 2x4-inch plank at $25 per thousand feet B. M.	9.27

*Boards used 3 times, so one-third of total cost is charged.

Nails, etc.	.23
200 stakes at 1 cent	2.00
Interest and depreciation.	.15
Superintendent, $1; foreman, 50 cents	1.50
Total for 800 feet of road	$23.65
Per lineal foot of road	2.96 cents

All curves were superelevated so that a vehicle going 20 miles per hour would ride easily. The subgrade was then rolled to great compactness and the grade checked by means of a templet moving on the side forms. Since a natural pit of excellent gravel existed at Healdsburg, gravel was substituted for broken stone concrete. It cost 72 cents per cubic yard delivered at any railroad siding along the work. The average haul from the railway to the work was 1½ miles and the cost of hauling was 63 cents per cubic yard.

Using this gravel and a 1:6 mixture, it was determined that 96 sacks of cement would make 100 feet of the pavement. The gravel was piled continuously along the middle of the subgrade and the cement placed in 4-sack piles spaced 4 feet apart. A cleat was riveted to the inside of the charging hopper of the mixer to indicate a 2-sack batch of 1:6 concrete. The gravel was handled by 6 men with square pointed shovels, while 1 man charged the cement. The mixer traveled on 3-inch redwood sills, shifted to guide it well. This runway was located midway between the side forms. The subgrade was wetted down ahead of the mixer. Concrete was distributed by a chute and was also shoveled against the side forms. No expansion joints were used, under the theory that allowing the natural cracking of the pavement, and afterwards filling the cracks with a bitumen, would form the best expansion joints.

The labor costs on the concrete were as follows:

	Costs per day
1 foreman at $4.00	$ 4.00
1 engineman at $3.00	3.00
10 shovelers at $2.75	27.50
1 cement man at $2.75	2.75
2 finishers at $3.00	6.00
Depreciation of plant and tools	9.00
Cost of water	6.13
Total	$57.83

The average daily run of concrete was 550 linear feet or 101.85 cubic yards, making the cost of placing the concrete 10.4 cents per linear foot of 15-foot roadway or 56.3 cents per cubic yard, with the concrete materials delivered on the subgrade.

All water on this work had to be pumped. The pumping was done by means of a gas engine, pumping from adjacent streams and in one case from a specially bored 180-foot well. The cost of water averaged $18.40 per day. The water was used in about equal quantities for mixing concrete, curing concrete and wetting the subgrade.

Four different methods of finishing and curing the concrete slab were investigated. The first plan was to broom the surface with a steel broom 6 hours after placing, in order to roughen it so that the bituminous covering would cling. After 12 hours, sprinkling began and the concrete was kept moist. With this plan, the concrete could not be kept evenly moist and much water ran off and was wasted. The second plan was to broom the concrete as in the first, then to build earth dams along the pavement edges, then wet down the pavement and cover it with 2 inches of earth and water the covering until it was saturated and the water showed in pools. A third plan was, after brooming the concrete, to sprinkle it and cover it with heavy building paper held down by clods and stones. The idea was to remove the paper, resprinkle and replace the paper every night for 7 nights, the standard curing period. The plan reduced labor but the paper was torn off in places by the wind and did not protect the pavement from drying out in spots. A fourth plan was finally devised, eliminating most of the faults of preceding plans. Levees were first built along the edges and over the side forms in such position that about one-third the width of the embankment fell inside the form board and over the concrete. These side levees were built high enough to hold a depth of 2 inches over the crown of the slab. At suitable intervals, depending upon the grade, cross levees connecting the side levees were built. This divides the pavement up into a series of basins which were filled with water, one filling sufficing for the total curing.

The following table shows the costs of curing concrete pavement by the methods described, the third being omitted as impractical:

	Plan 1	Plan 2	Plan 4
1 man at $2.75 per day	....	$ 2.75	$ 2.75
Men at $2.50 per day	12.50	17.50	10.00
Depreciation, shovels, etc	.40	.80	.65
Cost of water	6.13	6.13	6.13
Supervision	1.50	1.50	1.50
Total cost first day	$20.03	$28.68	$20,53
Lineal feet covered	300	550	550
Cost per lineal foot, first day	$0.067	$0.052	$0.037
Cost of each consecutive day	0.067	0.052	0.005
Total cost of curing, 7 days, per lineal foot of pavement	0.469	0.364	0.067

The side form boards were removed 7 days after placing the concrete at a cost of about 1 cent per lineal foot of pavement. The earth levees were left in place about a week longer and were then removed with a 4-horse road scraper at a cost of about 0.3 cents. The shoulders were brought as near grade as practicable with the same scraper. The preparation of the shoulders, including rolling cost about 6 cents per lineal foot of pavement.

The following table shows the costs of paving:

	Per foot of road
Tearing up old roadway with rooter and plows	$0.0283
Placing form boards (after grading has been done)	0.0296
Handling and preparing subgrade with rolling	0.0375
Cost of pouring and finishing 4-inch concrete pavement	0.1043
Cost of curing and finishing, Plan 4	0.0670
Cost of removing form boards	0.0100
Cost of cleaning earth off pavement	0.0030
Cost of preparing shoulders	0.0600
Actual cost per lineal foot	$0.3397
Actual cost per mile	$1.793.62
10 per cent for contingencies	179.36
Total cost per mile	$1,972.98

These costs are exclusive of costs of materials for the pavement itself and of excavation and fill. These costs were compiled by C. L. Rakestraw, resident engineer for the California Highway Commission, and appeared in *Engineering and Contracting.*

At La Salle, Illinois. An interesting piece of concrete road was built at La Salle, Ill., in the summer of 1913, under the direction of the Illinois Highway Commission. This road was described in a paper before the Illinois Society of Engineers and Surveyors, by Mr. A. H. Hunter, division engineer of the commission, who was in direct charge of the work.

The road is known as the Bottom Road, and has 75 per cent of its length subjected to the ravages of the

Illinois river during flood time; the remaining 25 per cent is on a bluff and runs under a railroad viaduct, up a 6 per cent grade over the Illinois and Michigan canal, and up another nearly equal grade to a bridge over another railroad.

The Illinois Highway Commission prepared plans for a 20-foot concrete roadway having a thickness of 6 inches at the sides and 7 inches in the middle, shaped to a crown of 3¾ inches. The road was built by day labor (excepting hauling, which was contracted) under the direct supervision of the commission. The commission furnished (free of charge) a 10-ton road roller and a concrete mixer, with an operator for each. The old macadam surface was loosened with a scarifier drawn by a 10-ton roller, the loose stone being then shaped to the crown of subgrade and thoroughly rolled. An abundance of stone dust remained on top, so a thorough wetting with water from the pipe line and an occasional trip of the roller prepared a sub-base, which gave an excellent foundation for the concrete and furnished a smooth surface for the shoveling of the gravel. Drainage for the foundation was provided by longitudinal ditches 8 inches wide and 6 inches deep under the outer edge of the concrete. At the end of the expansion joints a lateral drain, consisting of a trench filled with gravel, led to the riprap wall of the fill.

The aggregate consisted of clean, washed gravel, screened to sizes ranging from ⅜ to 1¼ inches, and pure sand. The gravel was composed of granite pebbles in well graded sizes, with no loam, clay or disintegrated material. The sand was sharp and clean but rather fine. On the rolled subgrade, the loads of gravel and sand were dumped in rows. The quantity of sand and gravel per lineal foot of road was computed, and the wagons were measured and loads spaced accordingly. An effort was made to have all loads the same size, as this simplified matters for the man who dumped, and relieved the engineer of the incessant checking of quantities. To allow for waste and variation in thickness, 10 per cent excess of material was provided. This proved sufficient, as there was not an excess or deficiency of more than 10 cubic yards of sand and gravel in the whole road.

As a large amount of water is required, both for mixing the concrete and for the proper curing of the finished road, it is the practice of the Illinois Highway Commission to construct pipe lines to which water may be furnished by city pressure or by a pressure pump operated by a gasoline engine. At La Salle, connection was made to the city water system and a 1¼-inch pipe line with T's every 300 feet was laid along the road. With 150 feet of hose connection attached to the mixer, it was possible to secure water at all points, although at the extreme end of the line the pressure was not sufficient to sprinkle the finished road work while the mixer was running.

A self-moving batch mixer was used, having a low hopper in front into which sand and gravel were shoveled direct from the road. Two sacks of cement were used for the batch. The concrete was deposited in place by means of a 20-foot horizontal rotating boom on which operated a traveling dump bucket. This equipment made it possible to deposit the concrete on any spot of the wide base. The work averaged 450 square yards per 8-hour day. The concrete was struck off to crown and grade with a steel-shod template cut to the crown of the roadway.

Expansion was taken care of by means of ⅜-inch asphalt joints placed 50 feet apart at an angle of 60 degrees with the center line of the road. The edges of these joints were protected by Baker plates, cut to the crown of the road, having their edges flush with the

Austin Cube Mixer on La Salle Road.

surface. The edge of the concrete was retained by wood forms consisting of pine pieces 2x6 inches, 16 feet long, resting on edge, held to alignment by ⅝-inch iron pins 18 inches long. It was found difficult to butt the boards together perfectly, so the more imperfect form pieces were cut in 2-foot lengths and used for splices, being nailed to the outside of the forms. This gave good results, especially on curves, where it was possible to align arcs of circles almost perfectly.

The mixture used was 1:2:3½, by volume. A box containing 0.95 cubic feet was constructed and for each sack of cement placed in the hopper of the batch mixer, two boxes of sand and 3½ boxes of stone were added. The shovels of sand and stone necessary to secure the repective amounts of material were counted and this number used for each batch. When new shovelers were placed on the gang, the box was used to check the amount. The stone determined in this manner varied but slightly, but the sand had to be changed frequently.

The actual cost of the work was obtained by adding the daily expenditures, the cost of hauling and the market price valuation of the donated materials, inclusive of freight and all incidental items. To this were added the salaries of the resident engineer and the roller and mixer operators. In all 10,663 square yards of surface had been improved at a cost of $13,632. The common labor used was foreign and received 35 cents per hour, and teams received 62½ cents per hour. The itemized cost per square yard for labor and supplies is as follows:

Superintendence	$0.023
Excavation, shaping road bed and trimming side roads	0.158
Hauling sand and stone	0.169
Mixing and placing concrete, setting forms and filling joints	0.133
Watchman and miscellaneous labor	0.116
Sand and stone, f. o. b. siding, including demurrage	0.314
Cement, f. o. b. siding, including demurrage	0.310
Expansion joints, f. o. b. siding, including demurrage	0.028
Coal and oil for mixer and miscellaneous supplies	0.021
F rms and other lumber	0.008
Total	$1.279

At Nazareth, Pa. During the summer of 1908, a street in Nazareth was paved with a two-course concrete pavement for a distance of 6 blocks, approximately 3,600 feet in length and 35 feet between curbs, the area paved being 13,625 square yards. The work was done under the supervision of Mr. Paul E. Kressly, now city engineer of Inglewood, Cal., and described by him in *Municipal Engineering.*

The clay loam subgrade was dressed and rolled to a grade of 8 inches below the surface of the finished pavement. On this the concrete base 5½ inches thick, was laid. This was a 1:3:6 mixture of cement, sand and crushed limestone.

The wearing surface course was 2½ inches thick, of a 1:1½:3½ mixture. The sand was such that 75 per cent would fail to pass a 30 mesh screen and the stone was graded from 1¼ to ½ inch. The sand and cement were mixed dry in the mixer, then enough water added to make a wet mortar and the mixing continued and then the stone added and the whole thoroughly mixed. Sufficient water was then added to make a "wet" concrete. This was placed on the base course, before the latter had begun to set the concrete was well rammed and finished with a templet. The surface was then rolled with a 5-ton power roller of the asphalt type. The pavement was kept moist by sprinkling for at least 10 days and no travel was permitted for 14 days.

Expansion joints were placed along the curbs, and longitudinal joints were placed 2 feet 3 inches outside each rail of a street railway track in the center of the street. Transverse expansion joints ¼-inch wide were placed 25 feet apart, and filled with a bituminous cement composed of coal tar pitch, to which was added

20 per cent of refined Trinidad asphalt and 20 per cent of hydraulic cement.

After more than 5 years of use on a street averaging 461 vehicles per day, 63 per cent of which are heavy teams, the pavement has fully demonstrated its usefulness and has given very satisfactory results up to date.

Concrete Roads in Ohio. Up to January 1st, 1914, the Ohio State Highway Commission had built 39.63 miles of concrete roads. These roads cost an average of $9,606 per mile, or $1.128 per square yard. These figures mean very little, however, as the pavements were of varying kinds, some of them one-course, others two-course, ome of them reinforced, and most of them with surface treatments of various kinds. They were also in widths varying from 10 to 20 feet, and in various thicknesses of slabs and different proportion of ingredients. In fact, they were put down as experimental pieces of road, to try out concrete as a road material.

This cost is the contract price paid and does not include the cost and expense of engineering and inspection, but does include the cost of grading and finishing of shoulders and ditches and a small amount of accessories. Deducting from this average cost the average cost of surface treatment, which is 9½ cents per square yard, there remains $1.033 as the average cost per square yard of plain concrete, including grading, shoulders and accessories. The average cost of grading, finishing of shoulders and ditches and acessories is $0.167 per square yard of paved surface. Deducting this from $1.033, we have 86.6 cents as the average cost per square yard of the plain pavement alone, exclusive of engineering and inspection costs.

CHAPTER XIV.

Some Data on City Pavements.

At Mason City, Iowa. Mr. F. P. Wilson, city engineer of Mason City, Iowa, has made an extensive study of concrete paving and has put down successive stretches of this pavement through a series of years, revising his specifications somewhat each year in the light of experience. Mr. Wilson makes this statement:

"It is my opinion from my observation and experience that a Portland cement concrete pavement, properly laid in an up-to-date manner, with first-class cement, good, clean, sharp sand, and good, clean, hard stone, with proper allowance made for contraction and expansion, with the edges of the expansion joints protected with softened steel plates, said protection plates anchored into the concrete on each side of the expansion joint, the pavement to be kept wet and protected from the sun at least eight days after it is laid, so that it cures out slowly, certainly warrants the use of cement paving on account of its first cost, cheapness to maintain, cleanliness of the streets, and the small expense to repair when it becomes necessary to cut holes.

"In constructing a first-class cement pavement the first requirement is to have first-class material; secondly, to have a first-class, up-to-date set of plans and specifications; and lastly, honest, rigid and close following of these specifications in every detail."

Mason City has adopted the two-course method of construction on account of the soft stone that is at hand in the locality, making a very satisfactory base but being entirely unsuited to making a hard wearing sur face.

The Mason City specifications as used by Mr. Wil son are given in Appendix C.

At Fort Smith, Ark. During 1912 the Board o Improvement of Paving District No. 5, at Fort Smith Ark., constructed by force account about 100,000 squar yards of concrete pavement at an average cost of 69.4 cents per square yard. This cost includes the remova of about ¼ yard of earth per square yard of pavemen in the grading and the rolling of the sub-grade. It als includes a 10 per cent allowance for depreciation o equipment, but no charge for superintendence. Th pavement was 6 inches thick, of the 1-course type, un reinforced, and was made of 1:2:4 concrete.

The construction of this pavement was describe by the engineer, Mr. George Myers, in *Engineering an Contracting.* The main equipment consisted of a No 23 Chicago batch concrete mixer and ¾-yard Brigg one-horse carts, besides the usual grading implements Portland cement on an average cost $1.18 per barrel gravel and sand averaged $1.25 per cubic yard; broke stone, crusher run, averaged $1.20 per cubic yard. Th above prices are for materials delivered on the job. Common labor was paid for at the rate of 15 to 2 cents per hour; enginemen at 25 cents; foreman, $12 per month, and teams 35 cents per hour.

The cost of the concrete was as follows:

	Per cu. yd
1½ bbls. cement at $1.18	$1.77
0.4 cu. yd. sand at $1.25	.50
0.9 cu. yd. broken stone at $1.20	1.08
Mixing, carting, laying and cleaning up	.49
Total	$3.84

This figures out 64 cents per square yard; adding 5 cents per square yard for grading and .4 cent per square yard for rolling makes the total cost 69.4 cents per square yard.

The method of construction was as follows:

The sub-grade was shaped to conform to and be 6 inches below the finished pavement. The concrete mixer and material were placed about midway of each section of the work, but off to one side. The carts brought the concrete to one end of the work and it was deposited between ¼x6-inch steel templates 20 feet apart, the entire width of the roadway. The concrete was quite wet and was tamped by means of a heavy steel-shod straight edge, and then floated with a 2x4-inch yellow pine float, 22 feet long, in order to reach well beyond the templates. Segments of red building paper were placed next to each template before the concrete was placed and as soon as possible the template was withdrawn, leaving a contraction joint. The adjoining section was then laid in the same manner. An expansion joint was left every 60 feet.

At Lynn, Mass. In 1911 the city of Lynn, Mass., removed an old macadam road and replaced it with a one-course concrete pavement. The sub-base was made the same shape as the finished surface and was thoroughly rolled with a 12-ton roller.

The concrete was mixed in a batch mixer in the proportions one part Portland cement, two parts sand and four parts graded broken stone. The mixture was of a quaking consistency. Along each curb an expansion joint was made by means of a ⅝-inch band. There were no joints made across the street. Although the pavement is 2,000 feet long, no cracks are evident in it.

Before the concrete hardened the surface was roughened by brooming. All travel was kept off the street for one week.

The street is a fine example of permanent pavement. It was built by contract for $1.70 per square yard, including grading.

At Marshalltown, Iowa. In 1911 Marshalltown did a small amount of concrete paving, and in 1912 there were 60,000 square yards put down, the contract price on this being $1.08 per yard. This was considered a low price by the city engineer, and was accounted for in part by the fact that the contractor was not required to give a large maintenance bond, a rigid test of materials and inspection of the work being insisted upon. Materials were also secured at very reasonable rates.

An inspector was stationed at the mixer and another worked with the spreading and finishing gang. Each carload of cement was submitted to the standard tests of the American Society of Civil Engineers and the commissioners insisted that the gravel and sand grade up to specifications.

The combined sand and gravel was taken from the bed of the Iowa river and from old river channels in the valley inside the city limits. The aggregate was pumped and discharged over a one-quarter inch screen, separating the stone and sand. The small cost of pumping and screening, and the short haul from gravel beds to mixer, made the low cost of these materials an important item in the contractors' estimates.

A feature of the construction was the arrangement of the expansion joints and the method by which the filler was placed in them. All of the pavement was laid in residence streets. Most of it was 30 feet wide. The curb was not combined with the gutter but was poured separately. In addition to a joint ¾ inch wide next to each curb, a longitudinal joint ¼ inch wide was placed in the center of the street. Transverse joints also ¼ inch in width, were spaced at 15 foot intervals, dividing the pavement into blocks 15 feet square. All these joints extended down to the sub-grade. Those next the curbs were filled with an asphaltic filler. The longitudinal and transverse joints were filled with rubberoid, or a good grade of tar paper. This paper was put in while the pavement was being laid.

The method of placing the filler in the cross and lengthwise joints is a new one that has been adopted in few other cities. The pavement was laid only half the width of the street at a time. The paper was placed in the transverse joints as the concrete was spread and tamped. A strip of rubberoid 8 inches wide was held in place alongside a plank 5 feet long, while the concrete was being spread on both sides of the plank. The plank was then lifted, leaving the filler in place, with about an inch of it projecting above the wearing surface. After the pavement set, the protruding edge of the paper was trimmed with a sharp shovel flush with the top of the pavement. The longitudinal joint was established while the first half of the paving was being laid along one side, by staking a line of planks, 7 inches wide, along the center of the street. When the concrete had begun to set the planks were removed and strips of rubberoid were tacked to the edge of the finished side from which the planks had been taken. The top edge of the paper was set flush with the surface. The other half of the street was then paved.

The city engineer originated the idea of the join in the center of the street after he had observed, whe inspecting concrete pavement in other cities, that wher there was no such joint the pavement had cracked i more or less zigzag lines longitudinally near the cente of the street.* The central joint checks any transvers cracks from extending farther across than the center The crosswise and lengthwise joints divide the pave ment into 15-foot blocks, making it easy, if a bloc becomes defective from any cause, to remove it and la new concrete without affecting the rest of the pavement

Wanting to make a comparative test with anothe kind of filler for the longitudinal joint, the city en gineer secured waivers from property owners in on block, and, instead of placing rubberoid in the centra joint, the joint was cut and the cut was filled with pitch The object aimed at was to test the wearing qualities o the edges of the central joint when different fillers ar used. Eighteen months use shows that some of th edges of the longitudinal joints filled with rubberoi are chipping, but in most places they show no mor wear than the rest of the pavement.

This pavement consists of a 5-inch base, compose of 1 part cement, 3 parts sand and 5 parts gravel. Th 2-inch wearing surface is composed of 1 part cement t 2 parts of sand. The wearing surface is laid as soon as the base is spread, tamped and brought to grade, and is roughened with a coarse broom.

At Alpena, Mich. The following figures are taken from the report of the city engineer of Alpena, Mich., on work done during the summer of 1911:

*This probably indicates not the need of a central joint, but the need of greater strength at this point.

Water Street Pavement.

No square yards		707
Crushed stone	$ 49.00	
Gravel	70.00	
Cement, 274 bbls., at $1.20 net	328.80	
Asphalt filler	22.36	
Catch basins	23.28	
Armor plates for expansion joints	21.12	
Lumber for expansion boards, etc	9.04	
Labor, men	331.00	
Labor, teams	96.00	
Total amount		$ 950.60

Cost per square yard, $1.295.

Washington Avenue Pavement.

No. square yards		3,545
Crushed stone	$ 165.00	
Gravel	304.00	
Cement, 1,406 bbls. at $1.20 net	1,687.20	
Asphalt filler	77.49	
Steel for curb protection	12.60	
Armor plates for expansion joints	62.50	
Catch basins	58.20	
Lumber for expansion boards, curbing, etc.	45.37	
Labor, men	1,449.25	
Labor, teams	767.00	
Total amount		$4,628.61

Cost per square yard, $1.305.

Fletcher Street Pavement.

Amount paved by city, square yards		1,286
Crushed stone	$ 88.00	
Gravel	149.00	
Cement, 668 bbls.	801.60	
Asphalt filler	37.24	
Armor plates for expansion joints	28.16	
Steel for curb protection	3.85	
Catch basins	27.36	
Lumber, expansion boards, curbing, forms, etc.	21.67	
Labor, men	1,045.25	
Labor, teams	252.00	
Total amount		$2,454.13

Cost per square yard, $1.39.

Chisholm Street Pavement.

No. square yards		6,518
Crushed stone	$ 272.00	
Gravel	537.00	
Cement, 2,607 bbls.	3,128.40	
Asphalt filler	143.39	
Armor plates for expansion joints	147.40	
Steel for curb protection	16.80	
Catch basins	69.84	
Lumber, expansion boards, curbing, forms, etc.	83.92	
Labor, men	2,288.25	
Labor, teams	860.00	
Total amount		$7,547.00

Cost per square yard, $1.158.

Mill Street Pavement.

No. square yards		1,098
Crushed stone	$ 53.00	
Gravel	93.00	
Cement, 440 bbls.	528.00	
Asphalt filler	39.00	
Armor plates for expansion joints	27.50	
Lumber, expansion boards, curbing, forms, etc.	25.87	
Labor, men	545.00	
Labor, teams	206.00	
Total amount		$1,517.37

Cost per square yard, $1.382.

At Waterloo, Iowa. During the summer of 1912 the first concrete pavements were laid in Waterloo, Iowa. Two alleys, each in a different part of the city, were paved. The specifications called for a two-course pavement. In one alley 4-inch base and 1½-inch wearing surface was specified; the base to consist of 1-3-6 stone concrete, or 1-5 gravel, and the top 1-2 screened gravel, passing ¼ inch sieve, the top coat to be applied within 40 minutes of the time of placing the base. In the other alley the wearing surface was increased to

2 inches on account of heavier traffic. The surface coat was mixed wet enough so that the contour of the pavement could be forced by drawing a templet over it, after which the surface was troweled and then broomed.

Expansion joints were provided every 25 feet transversely, and contraction joints midway between the expansion joints. Expansion joints were made by placing two rows of vitrified brick blocks, separated by a board ⅜ inch thick, end to end across the width of the alley. These brick were placed after the base was put in, and were embedded in the base so that the upper part of the bricks conformed to the curve of the finished surface of the pavement. The top or wearing surface was mixed wet enough so that the mortar flowed into the cracks between the ends of the bricks, holding them firmly in place. The spacing board was taken out as soon as the concrete had hardened sufficiently, and none of the bricks were displaced in removing the board. The joint was afterwards filled with asphalt.

The pavements are required to be guaranteed for a period of one year. Both alleys seem to be in very good condition now, and have not shown any signs of wear or deterioration. The cost was $1.12 per square yard for the 5½-inch pavement and $1.25 for the 6-inch concrete.

At Aledo, Ill. During the year 1912 a comparatively large yardage of concrete pavement with a wearing surface of bitumen and sand was laid at Aledo, Illinois. Throughout the business section of the town a strip of brick pavement 6 feet wide was laid between the concrete pavement and the curbs. The contract price for the brick pavement on a 6-inch 1-2-4 concrete base with 1-inch sand cushion was $1.62. The contract price for the concrete pavement consisting of 6 inches of 1-2-4 concrete was 86 cents per square yard. The bitumen for the wearing surface was furnished the contractor by the city. The contractor furnished sand and labor and laid the wearing surface for 10 cents per square yard. Allowing 20 cents per gallon as the cost of bitumen, this would make the total cost of the concrete pavement approximately $1.06.

Cost of Pavement at Boise. The city of Boise, Idaho, has over 85,000 square yards of concrete pavement in service, the cost of the various sections of which is shown in the accompanying table. It is all one-course work, with surface finished with wood float. The mixture used is 1:3:7, and the price of cement is figured at $2.75 per barrel and sand and gravel at $1.00 per cubic yard. The price does not include grading. The thickness on all the work is 6 inches, except the first one, which is 8 inches.

Total Sq. Yds.	Contract price per sq. yd.
20,183.92	$1.155
6,877.92	1.10
27,018.00	1.09
27,847.36	1.15
3,482.12	1.04

Sand Cushion Between Courses. The city of Oshkosh, Wis., has laid some pavements of two layers of concrete separated by a sand cushion, the same as though a wearing course of brick or block were being laid.

The method of construction of this type is substantially as follows: After grading and compacting the sub-grade a concrete foundation 4 inches thick is placed on this, the concrete being composed of one part of cement, 4 parts of sand and 8 parts of crushed stone, the stone being not over 2½ inches in size. On this foundation is placed the sand cushion of fine dry sand and spread ½ inch in thickness. Reinforcing bars are then placed, these being ⅜-inch twisted bars, spaced 2 feet apart in both directions. The bars are wired together at the intersections and lap 8 per cent of their length at the joints. They are held in place by chairs so that they will be uniformly 2 inches below the top of the finished concrete surface.

Laying Pavement at Oshkosh, Wis.

After the reinforcing is placed the top course is laid directly over the reinforcing and on the sand cushion. This top course is 5 inches thick and is composed of 1 part cement, 2 parts sand and 3½ parts of crushed stone. Expansion joints are protected by armor plates between which are placed strips of Carey elastite No. 1. Half way between expansion joints a contraction joint is put in, which is made by setting up Carey elastite before the concrete is laid and holding it in place with stakes until the concrete is placed. This filler is ¼ inch in thickness.

After the surface of the concrete is troweled, it is roughened by the use of a plank with strips of iron fastened longitudinally to the side. This plank is laid on the concrete, forcing the strips of iron into the surface thus making indentations in it ¼ inch in depth and about 2 inches apart. The surface is then covered with wet sand as soon as possible after marking; and after it has thoroughly dried, it is given a finish coat of distilled tar about ⅛ inch in thickness and is then covered with about ½ inch of sand or a mixture of sand and pea gravel. This is rolled with a 5-ton roller.

Oshkosh has also built a number of pavements with a sand cushion on top of the subgrade, the idea being to make the pavement proper as independent as possible of changes in the subgrade.

At a Manufacturing Plant.—Concrete pavements exclusively for traction engine use have been built throughout the yards and shops of the Avery Company at Peoria, Ill. For driveways the slabs are 15 inches thick, of 1 part Portland cement and 7 parts pit-run gravel, the latter being excavated on the company's property. Edges of the pavement are protected from spalling by a 2x8-inch plank laid flat and flush with the surface of the road. The planks are secured to the concrete by bolts with countersunk nuts and washers spaced on 2-foot centers so as to permit renewals to be made. While a 1 to 2-inch wearing surface of rich mixture is placed, it is the intention to keep the surface covered with from 2 to 4 inches of cinders so as to eliminate excessive wear on the concrete from the cleats on the drivers of the engines.

CHAPTER XV.

Reinforced Concrete Pavements.

Reinforced concrete pavements have been built in a number of localities, and with seemingly excellent results, though the term of experience has scarcely been sufficient to determine whether their behavior or life are superior to that of ordinary concrete. It is easily conceivable that in building over fills, or otherwise unstable ground, reinforcement would be a decided advantage in helping to distribute the load and thus prevent an undue concentration of weight on any one part of the sub-base. For pavements exposed to a constant heavy traffic, such as in the vicinity of plants where heavy machinery is manufactured, and the like, reinforcement ought also to add materially to the life of the structure.

One advantage claimed for reinforcement is that it serves to make of the pavement a more homogeneous mass. It is well known that the ratio of expansion and contraction of concrete depends to a considerable extent upon the proportion of cement contained. With a lean mixture as a base, therefore, covered by a rich top coat, the two courses will have different coefficients of expansion, with a consequent tendency of the two courses to crack apart. The introduction of reinforcement will to a certain extent counteract this tendency and help the two courses to act as a unit.

It is expected of reinforcing that it will reduce the tendency of the concrete to crack on account of changes in temperature, variations in the percentage of moisture, defective foundations, improper drainage faulty construction, insufficient thickness of slabs, o for any other reason. While a greater spacing of ex pansion joints is probably allowable in reinforced con crete pavements than in those without reinforcing, i should be borne in mind that the reinforcing should no be expected to cover deficiencies in construction, excep such as happen by accident. The concrete in a rein forced concrete pavement should be just as carefully made and laid as though it were to take all the strain of the pavement rather than to be assisted by the rein forcing. It is because of the fact that reinforcing seems to give some contractors an idea that they can be careless in their construction in other ways, tha many engineers do not favor reinforcing of concrete pavements. If, however, sufficient care is taken in other respects—in fact, the same care that would be exercised in a plain pavement—reinforcing will un doubtedly add materially to the strength of the struc ture.

One of the most usual methods of reinforcement is by the use of a sheet of wire mesh or expanded meta laid on the base course of concrete and tamped so that at least 50 per cent of the wire is covered. The rein forcement should preferably be placed with the longi tudinal wires parallel to the center of the pavement, and covering the space between joints completely but not extending across the joints.

The latest specifications of the American Concrete Institute provide that all concrete pavement over 20 feet in width shall be reinforced with metal fabric. As to the amount of metal, it is specified that the cross-sectional area of the reinforcing running parallel to the center line of the pavement shall amount to at least 0.038 square inch per foot of pavement width, and the cross-sectional area of reinforcing metal, perpendicular to the center line of the pavement, shall amount to at least 0.049 square inch per foot of pavement length. This is equal to about a No. 29 Triangle mesh or a Clinton wire cloth of 4x12-inch mesh made of 3 and 8-gauge wire.

The specifications also provide that the reinforcing shall not be placed less than 2 inches from the finished surface of the pavement; that the reinforcing shall extend to within at least 2 inches of all joints, but shall not cross them, and that adjacent widths of fabric shall be lapped at least 4 inches.

While the amount of reinforcing given is an average amount, it should be determined in each case by an engineer familiar with local conditions. The range in temperature and the percentage of moisture varies with each locality, as does also the character of the traffic over the roadway. It is evident, therefore, that each roadway must be studied to suit these conditions. The soil conditions will also vary with the locality. It will be found advantageous to use additional reinforcement where the subsoil is of an inferior character, or the road is on a hill. All these things, however, must be determined by an engineer who is familiar with the locality.

Following are given a number of examples of reinforced concrete pavements and the data concerning them:

One of the first pavements constructed using a reinforcement was laid at Plymouth, Wis., during the summer of 1910. Approximately 11,000 square yards were laid at that time at a cost of $1.235 per squa[r]e yard including the grading. This pavement consiste[d] of what is known as a two-course type, the base bein[g] made 5 inches thick and the top or wearing course 1½ inches thick, making a total of 6½ inches. The specif[i]cations called for a concrete mixture in the proportio[n] of 1:3½:6 for the base, the crushed stone to be fre[e] from dust and of varying sizes, all of which shall pa[ss] through a 2-inch ring and be held on a ½-inch ring, th[e] sand to be of such a size as will pass a ¼-inch squar[e] mesh. The top or wearing course consisted of 1 par[t] of cement to 1½ parts of crushed granite, the granit[e] to be properly graded from dust to ½ inch in size[.] After placing the bottom course, triangle mesh rein[-]forcement No. 7 was laid, the longitudinal wires bein[g] placed crosswise of the street, after which the wearin[g] course was placed before the base had taken any appre[-]ciable set.

The top course was troweled to a smooth finis[h] and while still soft, granite screenings varying in siz[e] from ¼ to ¾ of an inch were scattered over the entir[e] surface, the idea being to produce a surface that woul[d] be practically smooth and at the same time one tha[t] would not be unnecessarily slippery. Expansion joint[s] were placed every 40 feet across the pavement and als[o] along the gutters. On streets having street car tracks, joints were also placed on each side of the track at the end of the ties. These joints were made by using 1x8 inch cypress boards for forms, these boards being allowed to remain in the work and form the filler for the joints. Engineers have reported this pavement to be in excellent condition after two and one-half years' wear. It was designed by Mr. W. G. Kichoffer, consulting engineer of Madison, Wis., who also supervised the work.

During the year 1911, Sheboygan, Wis., had approximately 15,000 square yards of reinforced concrete pavement laid and during 1912 approximately 45,000 square yards. The base consisted of 5 inches of concrete mixed in the proportion of 1 part of Portland cement, 3 parts of sand and 5 parts of crushed limestone, and was laid 5 inches thick at the center of the street and 3 inches at the curbs. The wearing surface was 1¾ inches thick and consisted of 40 per cent of Portland cement, 50 per cent of granite screenings and 10 per cent of torpedo sand. The granite screenings were graded to 20 per cent having a size of 1-16 to ¼ of an inch and 30 per cent ¼ to ¾ of an inch. Triangle mesh No. 7 was laid between the wearing surface and the base, the longitudinal wires being placed crosswise of the street. The wearing course was floated by means of a wood float after which the surface was broomed transversely to give a slightly roughened surface. The pavement was sprinkled for seven days and no teams were allowed upon the same for ten days. One-inch expansion joints filled with asphalt were constructed along the curbs and every 40 feet across the street. These pavements were designed by City Engineer C. V. Bowley, the contract price being $1.20 per square yard.

The City of Fond du Lac, Wis., has made extensive use of concrete pavements, both plain and reinforced, having constructed during 1908 approximately 17,300 square yards of plain pavement at an average price of $1.325 per square yard, and in 1909 approximately 69,200 square yards at an average price of $1.235 per square yard. Since 1910 their concrete pavements have

all been reinforced, using triangle mesh No. 7 for a width of 18 feet down the center between curbs, the principal reason for using the reinforcement being to eliminate the longitudinal cracks that formed in the plain pavements along the center line of the street. For the year 1910 the average price for 44,300 square yards was $1.177 and for 1911 the average price of 11,000 square yards was $1.25. An additional 8,000 square yards were laid during the year 1912. All pavements carry a five year guarantee, so that for the first five years at least there will be no maintenance charges.

The usual type of combination curb and gutter is first constructed, after which the center portion of the street is excavated and rolled to the proper elevation. Upon this foundation is laid a 5-inch base course consisting of 1 part of Portland cement, 2½ parts of sand and 5 parts of clean crushed limestone, 4 inches being laid first, upon which is placed the wire fabric reinforcement, the longitudinal wires running crosswise of the street, and immediately thereafter is placed the additional 1 inch of concrete. The wearing surface is immediately applied and consists of 1½ inches of a mixture of 1 part of cement, 1 part of clean sharp sand and 1 part of crushed granite, this granite consisting of sizes ranging from dust to ¼ of an inch. The surface is then troweled and before hardening it is roughened by brushing crosswise with an ordinary street broom. Expansion joints are placed along each gutter and every 50 feet across the street and have a width of ¾ of an inch. The forms for the expansion joints are allowed to remain in place until the concrete is hardened, after which they are removed and the joint is filled with an asphalt preparation. The surface is kept wet for one week and then the street is thrown open for traffic.

The pavements have been designed and the construction supervised by J. S. McCullough, city engineer for Fond du Lac.

During the year 1912, Superior, Wis., laid 9,602 square yards of reinforced concrete pavement designed by City Engineer E. B. Banks. The base consisted of 6 inches of concrete mixed in the proportion of 1 part of Portland cement, 2½ parts of sand and 5 parts of crushed stone. The top or wearing course is 1½ inches thick and consists of 1 part Portland cement, 1 part of sand and 1 part of crushed trap rock varying in size from ¼ to ¾ of an inch. The reinforcement used was triangle mesh wire fabric, style 29, placed with the longitudinal wires crosswise of the street and extending from curb to curb. The first 4 inches of the base were placed upon the rolled foundation and upon this was laid the reinforcement, after which the additional two inches of the base were laid. Immediately upon this completed base was placed the wearing course, which was troweled and roughened by brushing with a street broom. One-half inch expansion joints were placed along the curbs and across the street every 24 feet. The finished pavement cost $1.29 per square yard exclusive of the excavation, the material and labor costs being as follows:

Cement, per barrel	$1.35
Sand, per cubic yard	.75
Crushed stone, per cubic yard	1.65
Common labor, per day	2.50

The City of St. Johns, Mich., laid during 1912 approximately 15,000 square yards of reinforced concrete pavement consisting of a base 5 inches thick mixed in the proportion of 1 part of Portland cement to 7 parts of gravel including sand. The top or wearing course is 2 inches thick mixed in the proportion of 1 part of Portland cement to 3 parts of clean sharp sand. Triangle Mesh No. 29 was used as a reinforcement, the same being placed between the base and wearing courses. Expansion joints were constructed along the curbs and across the street every 30 feet, all joints being protected with the Baker armor plate. This pavement was designed and supervised by E. G. Hulse, city engineer.

A very successful reinforced concrete pavement has been laid in Hamtramck, Mich. (a suburb of Detroit), the same having been designed and constructed by the R. D. Baker Company, Detroit, Mich. During the year 1912, 15,000 square yards were laid, having a base 5 inches thick consisting of a concrete mixture of 1 part Portland cement, 3 parts of sand and 6 parts of crushed stone. The wearing course is 2 inches thick, mixed in a proportion of 1 part Portland cement, 1 part of sand and 2 parts of crushed granite having a size not to exceed ½ inch. The reinforcement used was triangle mesh No. 28, placed between the base and top course and laid with the longitudinal wires at right angles to the center line of the street. Expansion joints were placed along the curbs and every 30 feet across the street, and were protected by means of the Baker armor plates. The cost of the finished pavement was $1.35 per square yard, exclusive of excavation, the material and labor costs being as follows:

Cement, per barrel	**$1.02**
Sand, per cubic yard	**.75**
Crushed stone, per cubic yard	**1.15**
Crushed granite, per cubic yard	**3.15**

All above being f. o. b. cars, Hamtramck.
Common labor cost $2.60 per day.

The City of Port Huron, Mich., laid about 9,000 square yards of reinforced concrete pavement in the year 1912. This pavement had a total thickness of 7 inches, consisting of a 5½-inch base and a 1½-inch wearing course. The concrete for the base was mixed 1 part Portland cement to 5 parts of river run gravel. The wearing course consisted of 1 part cement, 1½ parts sand, and 1½ parts of ¾-inch crushed field stone. Triangle mesh reinforcement No. 4 was placed between the top and bottom courses. Expansion joints were placed every 16 feet across the street and where car tracks occurred joints were placed 1 foot from the track on each side for the full length of the street. All joints were protected by the Baker armor plate. The price of the finished pavement was $1.22 per square yard, exclusive of excavation. The material and labor costs were as follows:

Cement, per barrel	$1.02
Sand, per cubic yard f. o. b. the work	1.15
Gravel, per cubic yard f. o. b. the work	1.15

Common labor was $2.25 to $3.00 per day.

The City of Rockville, Ind., constructed during 1912 4,400 square yards of reinforced concrete pavement. This pavement was of a one-course instead of a two-course type. Although the use of a reinforcement necessitated placing the pavement in two layers, both layers consisted of the same concrete mixture, this being 1 part of Portland cement, 2 parts of sand and 2½ parts of gravel. The total thickness of the pavement was 5 inches and the reinforcement was triangle mesh No. 7, placed approximately in the center of the slab. The curb is 6 inches high and 5 inches thick, built directly upon the pavement and anchored to the same by means of steel loops placed every 5 feet. Expansion

joints occur every 33 feet across the pavement and are protected by means of the Baker armor plate, the joints being filled with tar. Finished pavement cost $1.10 per square yard, including excavation, and the material and labor costs were as follows:

Cement, per barrel	$1.25
Sand, per cubic yard	1.25
Gravel, per cubic yard	1.25
Common labor, per hour	.20

Very little excavation was required beyond surfacing to grade. The foundation consisted of a yellow clay which required the depositing of a small amount of gravel in some places. The crown of the street was 4 inches for a width of pavement of 26 feet.

During the year 1912, Vinton, Iowa, laid 11,000 square yards of a two-course reinforced concrete pavement of a total thickness of 7 inches. The 5-inch base course consisted of a mixture of 1 part Portland cement, 3 parts of sand and 5 part of crushed stone. The 2-inch wearing course was mixed 1 part of cement to 2 parts of clean sharp sand. The reinforcement used was Triangle mesh No. 26, placed between the top and bottom courses over the center 16 feet of the pavement and was laid with the longitudinal wires at right angles to the center line of the street. Expansion joints were constructed along curbs and across the street every 40 feet, these joints being protected with steel plates ¼ of an inch thick and 2 inches wide, the same being anchored into the concrete by means of anchor bolts. The cost of the finished pavement, exclusive of excavation, was $1.07 per square yard, the costs of material and labor being as follows:

Cement, per barrel	$1.00
Sand, per cubic yard for hauling	.50
Crushed stone, per cubic yard	1.30
Common labor, per nine-hour day	2.25

Connersville, Ind., contracted for the construction of 65,000 yards of reinforced concrete pavement during the year 1912 at a cost of $1.04 per square yard, including excavation. The base is 5 inches thick at the curbs and 7 inches at the center and the top or wearing course is 1½ inches thick over the entire pavement. The concrete for the base is mixed 1 part of Portland cement, 2 parts of sand and 4 parts of crushed stone or gravel. The mixture for the wearing course is 1 part of cement to 1½ parts of clean sharp sand. The pavement is reinforced with triangle mesh No. 7, placed between the top and base courses. Expansion joints protected by means of Baker armor plate and filled with an asphalt filler are placed along the curbs and across the street every 30 feet. The material and labor costs were as follows:

Cement, per barrel	$1.02
Sand, per cubic yard	.50
Gravel, per cubic yard	.45

All f. o. b. Connersville, Ind.
Common labor, $2.00 per day.

A large amount of work was also done during 1914 and was practically the same as that of the previous year, except that the price went up to $1.25 per square yard. This was due principally to the advance in the price of cement The price mentioned in each case is the contract price plus engineering superintendence. The streets were already graded and were used as gravel streets, so that the only excavation that had to be done was to take the old material out to be replaced by the concrete. The excavation and the rolling and preparing of the sub-grade were included in the contract price. The contractors did the work and furnished all materials. The pavements carry a five-year guarantee.

Laying Concrete Paving at Connersville, Ind.

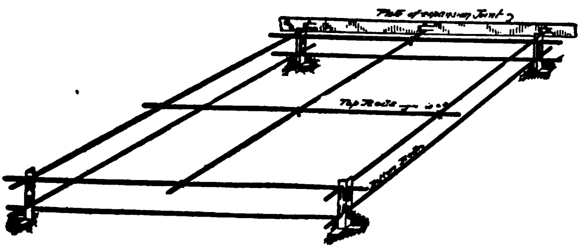
During 1912, Stanley, Wis., laid 9,000 square yards of reinforced concrete pavement having a total thickness of 6½ inches. The 5-inch base consisted of 1 part Portland cement to 5 parts gravel and the 1½-inch wearing course consisted of 1 part of cement to 2 parts sand and granite screenings. The reinforcement used was triangle mesh No. 7 placed between the top and bottom courses. Expansion joints were placed along the curbs and across the street every 30 feet. No steel protection was used on the joints but the edges were rounded to a small radius to prevent chipping off under traffic. This pavement was laid at a cost of $1.52 per square yard, including excavation.

The City of Mitchell, South Dakota, laid several blocks of reinforced concrete pavement during 1912, in accordance with plans and specifications furnished by S. H. Smith, city engineer. The base course was laid 5½ inches thick and consisted of a concrete mixed in the proportion of 1 part of cement, 3 parts of sand and 5 parts of crushed stone. The sand was to be well graded and to contain no pieces larger than would pass a No. 4 mesh screen. The crushed stone was graded in sizes ranging from ¼ of an inch to 2 inches. On top of the base was placed triangle mesh No. 7 for a width of 20 feet in the center of the pavement on Main street and 15 feet on intersecting streets. The main longitudinal wires were placed crosswise of the pavement and the entire mesh was tamped into the freshly laid concrete. Over this was placed the wearing course 1½ inches thick, consisting of 1 part of cement to 1½ parts of a mixture of equal parts of sand and stone screenings. In order to give the finished pavement a dark color there was to be added ¼ of a pound of lamp black to each sack of cement. The wearing course was properly floated to grade and troweled, and after becoming sufficiently hardened it was roughened with a street broom. Expansion joints ¾ of an inch wide were placed along all curbs, and joints ⅜ of an inch wide were placed across the street every 25 feet, and around all catch basins or man-hole covers. The edges of all expansion joints were rounded to ½-inch radius. After the pavement had taken sufficient set, the joints were filled with a suitable elastic waterproof compound.

The Township of DeKalb, Ill., constructed a short piece of reinforced concrete roadway pavement in 1912, the work being done under the supervision of A. N. Johnson, state engineer. The pavement consists of one-course work laid 6½ inches thick, the concrete mixture being 1, 2 and 3. Expansion joints were constructed across the pavement every 50 feet and protected by the Baker steel armor plate. Triangle mesh No. 26A was placed approximately in the center of the slab with the longitudinal wires at right angles to the center of the roadway.

The City of Davenport, Iowa, laid during 1911 several blocks of reinforced concrete pavement in which the reinforcement was placed near the bottom surface of the slab for structural reasons. The soil over which this pavement was to be laid consisted of refuse from saw mills, such as sawdust, chips, bark, etc., and was almost constantly saturated with river water. The street itself and the railroad track paralleling the same settled from eighteen to twenty-four inches every year. As the usual type of pavements could not possibly be expected to prove satisfactory with such a type of subsoil (the pavement also being subjected to heavy and high speed traffic) it was decided to construct a concrete pavement reinforced with a sufficient amount of steel to produce a monolithic slab that would spread over a greater area any excessive loads coming upon the same under the traffic conditions. The pavement was laid 7 inches thick of a 1:3:5 concrete mixture and reinforced with 0.5 per cent of triangle mesh reinforcement placed near the lower surface of the pavement. The total cost for the work was $0.93 per square yard.

Thomas Reinforcing for Pavements. This system of reinforcing is controlled by the Thomas Steel Reinforcement Company of Detroit, Mich. It is built up of ⅜-inch rods, ¾-inch rods, spacing members



Thomas Reinforcing for Pavement.

called stools, and facing plates for the expansion joints. The ⅜-inch round steel bars are placed longitudinally and crossways 2 feet center to center and 1 inch from the top surface of the finished concrete. The ¼-inch round steel bars are placed longitudinally and crossways 4 feet center to center and 4 inches from the top surface of the finished concrete, and both systems are well clamped together at their intersections. The two systems are properly supported in their respective places before any concrete is laid, and in proper lengths and widths so as to be embodied in concrete panels 30 feet long by the whole width of the road. The top and bottom bars are held firmly at intervals of 4 feet by an upright steel member, which will make a positively connected unit of the top and bottom bars through the whole pavement.

Expansion joints ½-inch wide are placed at right angles to the curb line at intervals of 30 feet. Joints have their edges protected by means of a soft steel plate 3-16 inch by 3 inch rolled to conform to the established crown of the pavement and the steel plates are securely attached to the reinforcing bars of the pavement so that the concrete between the expansion joints works as a unit. Expansion joints without steel plates are also placed along the side of the curb ½-inch wide and the whole length of the paved street, the opening extending to the bottom of the concrete base and the space filled with asphalt filler.

Generally the top bars are 2 feet center to center and those at the bottom 4 feet center to center, but this may vary according to climatic conditions. The vertical supports or stools are made of light angle iron sheared at the bottom so as to bend the feet, which give a bearing on the grade surface of the road.

If expansion joints are used every 30 feet and the street is 24 feet wide, the fixity of these stools, which are generally placed 4 feet on centers, makes a large stone 24 feet wide by 30 feet long, composed of small stones 4 feet by 4 feet, without any joint between the small stones.

This system requires about 50 tons of steel per mile of 24-foot pavement. The cost per yard is about 5 cents for edge protectors, 22 cents for other steel, and 3 cents for framing and placing.

CHAPTER XVI.

Concrete in Combination with Other Materials.

Because of a lack of a suitable supply of surfacing materials, or for other reasons, it may not always be desirable to construct the wearing surface of a road or pavement of concrete. But even when a top coat of some other material is desired, concrete can almost invariably be used to advantage as a base. For this purpose almost any local supply of stone or gravel can be used, and will give sufficient strength to carry the weight of traffic successfully, even though not adapted to come into direct contact with it.

Used in this way, concrete has many of the advantages inherent in a complete concrete road or pavement. It forms an unyielding base of sufficient strength to bridge over imperfections or weaknesses in the subbase, retaining its shape indefinitely and holding the wearing surface up to true grade and subject only to the wear on that surface itself; its monolithic nature keeps it secure from sinking into the soil; and its durability fits it to serve under an indefinite succession of wearing surfaces. It can be used to advantage as a base for any standard type of pavement, and would be put in approximately the same as the base for a two-course concrete pavement in the same location, except that expansion joints are not generally used.

Mr. Robert Hoffman, chief engineer, Department of Public Service, Cleveland, Ohio, has made a considerable study of various bases for brick pavements and gave the result of his investigations before the American Association for the Advancement of Science. He said:

"That an unyielding sub-base, such as concrete affords, is highly desirable goes without question, and it should be supplied wherever possible, and in most cases will prove more satisfactory, even at slightly greater cost. Concrete will carry the pavement load over the many soft places caused by street openings prior to paving and will prove a factor of safety against settlements and irregularities liable to occur where no concrete is employed. Any settlement in a pavement foundation breaks the bond of the brick and will be rapidly followed by serious deteriorations.

"Another possible economy in supplying a concrete foundation may be found in the possibility that some time it may be desired to replace brick with other kinds of paving material for which a concrete foundation must be supplied, such as wood block, asphalt or asphaltic concrete, in which event the cost will be materially lessened by reason of the existing concrete.

"In open country with poor drainage facilities, there is no doubt that the drainage effect of frost and the yielding sub-soil would soon depreciate any brick pavement with only a natural soil foundation, and there concrete is the only safe and economical foundation."

A bituminous surface is considered of advantage by many builders of concrete pavements, for taking the wear, giving a certain amount of resiliency, and giving greater freedom from noise. Mr. Logan Waller Page has also pointed out that such a surface ought to be of undoubted value, if put on soon after the concrete is placed, because of the fact that it will help to

Road Construction by the Hassam Process.

retain the original moisture in the concrete, thus allowing it to attain the fullest possible strength.

The application of such a coating is mentioned in connection with a number of jobs described in this volume. Descriptions of various patented types of such pavements are also given in Chapter XVII, and specifications are given in the Appendix.

In some instances an excellent concrete base has been made economically by installing a crusher on the job and crushing the stone from an old granite block pavement.

Cement grout is also coming to be recognized as the best filler for brick and stone block wearing surface. Some surprising comparisons have recently been made of brick pavements with cement filler and those with ordinary sand, showing the latter with joints empty and edges rounded in a comparatively short time, while the grouted joints show little perceptible wear after a number of years.

Crushing Old Stone Blocks for Concrete Base.

The leading engineers responsible for street paving design and construction are substantially agreed that the use of properly mixed and properly placed cement grout in place of sand or bituminous filler constitutes one of the most important improvements in brick paving practice that has taken place in decades. A grouted pavement becomes practically a continuous sheet. The bond of one brick or stone with those adjacent to it is so strong that it is practically impossible by any blow of traffic for a brick to be loosened and forced down lower than its neighbors. Again, the hard grout-filled joint protects the corners of the brick or stone, so that they are not rounded off by the attrition of horses' hoofs, as always happens in a few years on pavements where the joints are filled with less durable materials.

Such smooth-surfaced pavements can be kept clean and sanitary with far less expense than the old type of pavements, where dirt always lodged in the joints as soon as the pavement became at all worn. Still further, the grouted joints cost less than asphalt-filled joints, and a workmanlike job is much more easily secured with ordinary labor.

It must be borne in mind, too, that the whole paving question has a different aspect today by reason of the rapidly growing preponderance of motor traffic over horse traffic. The secure footholds for horses' calks afforded by the open joints of the old-time tar-filled brick or stone-block pavement are no longer essential. On the contrary, the nearer to a smooth plane surface a street can be kept, the less the wear and tear upon motor vehicles of all classes and the less the wear and tear also on the pavement itself. With the rubber-tired traffic of motor vehicles also one pavement is a good as another so far as noise is concerned.

The National Paving Brick Association advocate strongly the use of cement grout filler for brick pavement, as well as a concrete base. Speaking before th Association of Portland Cement Manufacturers, Mr Will P. Blair, secretary of the National Paving Brick Association, said:

"In the use of a cement filler, the important element of *ease of traction* is greatly assisted. By it a monolithic surface is formed, while the brick protects the thin portion or joint of cement, insuring a uniform wear upon the whole surface. In the earlier use of such a street the slight unevenness of the brick, which will obtain for the first few years, according to the amount of traffic upon the street, will prevent slipping and skidding which otherwise might occur owing to the film of glaze that is always present upon every No. 1 paving brick. As this glazed film in time disappears, the roadway becomes smoother, the granular surface follows, which for ease of traction is not found with any other form of pavement whatsoever, and is never approached in the case of a brick or stone pavement constructed with any other filler.

"The hardened joints of the cement filler are sufficiently rough and will stand the shock from the impact so that it will not shatter. With the relief afforded by the uniform two-inch compressed sand cushion, required as a necessary adjunct in the transmission of the load to the monolithic wearing plate, this joint is not broken. The vibrations of the impact upon the wearing plate are distributed without injury and the load is not concentrated wholly upon any individual brick. With the monolithic plate resting upon the uniform cushion support, the cushion itself is not affected or disturbed except to the minutest extent, whereas, in the use of the soft filler, a continuous maximum disturbance occurs, the brick being subject to a constant displacement. Their support cannot be uniformly maintained, hence the surface is divided into as many planes as there are bricks in the street.

"The force of the entire weight where the soft fillers are used is directed to the single brick as the wheel comes in contact with the same. The brick do not chip where the cement filler is used. They do chip where the soft fillers are used. The street grows better as it grows older, and the smoother it wears, the less slippery it becomes. Of course this does not hold good indefinitely, but it does hold good for an undetermined number of years. It is certain with the use of soft fillers, chipping at the corners and edges of the bricks immediately follows the use of the streets. In case of granite there results a smooth, rounded condition of the stone, subjecting the horses to most cruel and incessant short slipping, impairing their value and shortening their lives.

"The wear on the cement filled streets is scarcely perceptible from year to year. It is slight and level, and in continued harmony with the grade of the street. No waves or depressions are produced. Hence the impact is always at a minimum, and it follows the wear must be likewise so."

The following directions for the application of cement grout filler are recommended by the National Paving Brick Association:

"The filler shall be composed of 1 part each

of clean, sharp, fine sand and Portland cement. T
sand should be dry. The mixture, not exceeding
sack of the cement, together with a like amount
sand, shall be placed in the box and mixed dry, un
the mass assumes an even and unbroken shade. Wa
shall then be added, forming a liquid mixture of t
consistency of thin cream.

"The sides and edges of the brick should be th
oughly wet by sprinkling before the filler is applied.

"From the time the water is applied until the l
drip is removed and floated into the joints of the bri
pavement, the mixture must be kept in constant motic

"The mixture shall be removed from the box
the street surface with a scoop shovel, all the while l
ing stirred in the box, as the same is being thus emptie
The box for this purpose shall be 4 feet, 8 inches lon
30 inches wide and 14 inches deep, resting on legs
different lengths, so that the mixture will readily flo
to the lower corner of the box, which shall not be mo
than 6 inches above the pavement. This mixture, fro
the moment it touches the brick, shall be thoroughl
swept into the joints.

"Two such boxes shall be provided in case th
street is 20 feet or less in width; exceeding 20 feet i
width, 3 boxes should be used.

"The work of filling should be carried forward i
line until an advance of 15 to 20 yards has been made
when the same force and appliance shall be turned bac
and cover the same space in like manner, except tha
the mixture shall be slightly thicker for the second
coat.

"To avoid the possibility of thickening at an
point, the surface ahead of the sweepers and ahead o

e mixture shall be gently sprinkled, using a sprink- ag-can, the head of which shall be perforated with aall holes.

"Any attempt to thin the mixture on the pave- ent by the application of water will result in the paration of sand and cement, and 'bad spots' will ap- ear in the pavement where this practice has been per- itted.

"After the joints are thus filled flush with the top f the brick, and sufficient time for hardening has apsed, so that the coating of sand will not absorb any oisture from the cement mixture, ½ inch of sand iall be spread over the whole surface; and in case the ork is subjected to a hot summer sun, an occasional rinkling, sufficient to dampen the sand, should be llowed for two or three days."

Louisville, Ky., has been an advocate of and a iilder of brick streets for years. It is located near me first-class brick plants and the relative ease of tting the material, as well as other considerations, d to many miles of street of this type being con- ructed. Sand filler was used exclusively. The results ere extremely unsatisfactory. Instead of lasting ten, venty or twenty-five years, as it is claimed that brick ill do under proper conditions, the work went to eces in a few years, and irregularities, gradually eveloping into large holes, made their appearance most immediately after use was begun. It is con- ded that a large part of the defects were due to the e of poor paving block, but it is also believed that the iaracter of the filler was responsible for the chief ouble.

In 1909 the municipality decided to face about on

the grouting proposition, and specified that cement filler be used. The first year that the work was done under these specifications fair results were obtained; but since then, as inspectors and contractors both have become accustomed to the method, and know exactly how the filler should be applied, really magnificent streets have been built. There are some stretches of brick streets in Louisville, laid in cement grouting, that are pronounced by experts to be the equal of any in the United States. Certainly they are free from irregularities, absolutely smooth, are wearing down uniformly and have joints which give not the slightest indication of opening up or permitting the street to disintegrate.

Another big disadvantage of the sand filler is seen in connection with the use of modern street cleaning methods. Flushers which throw out water with considerable force tear the grouting out of a street on which a soft filler is used and leave it in a deplorable condition. In the case of cement, of course, the action of the water is not at all harmful, and street flushing machines may be used without question.

The success of the cement grouting system has been so great with reference to brick streets that the Board of Public Works of Louisville has extended it to granite streets. In this case, the joint, instead of being from 1/8 inch to 1/4 inch in thickness, as in brick streets, is from 1/2 inch to 1 inch thick. The blocks are rammed instead of rolled and a little gravel is swept into the joints to hold the blocks steady while they are being rammed.

The following suggestions for grouting granite blocks were given by Mr. William A. Howell in a paper before the American Society for Municipal Improvements:

1. Be sure your sub-grade is well rolled, and all soft places eliminated. The concrete should not be too rough and should be laid to a true crown. A uniform thickness of two inches of sand bed under the blocks should be maintained.

2. The blocks, after careful culling, should be well rammed.

3. Be absolutely sure the cement is good and the sand is clear and sharp. A small percentage of clay, not over 5 per cent, is preferable to act as a binder.

4. Great precautions should be taken to have the correct proportions of sand and cement in the mixture.

5. Keep the mixture continually agitated in the box; always remove the ground mixture from the box with scoop shovels. The contents of the box should never be dumped on the street; wherever this is done there is always a bare spot in the grouting.

6. The blocks should be thoroughly wet by sprinkling immediately before grouting.

7. Grouting should not be attempted during cold or frosty weather. Good results are seldom secured after November 15th in the latitude of New York city.

8. If the grouting is done during very hot weather, it should be immediately covered with a half-inch coating of sand which should be kept constantly moist by frequent sprinkling during the continuation of the hot spell.

9. Traffic should be kept away from the grouted pavement for at least seven days.

10. If the best results are desired with a minimum amount of effort, the use of a moderately soft

granite, similar to New Hampshire granite, is recommended.

Experience at Appleton, Wis. Concrete pavements with bituminous wearing surface have been used for the past four years in Appleton, Wis., with very good results, according to C. H. Vinal, the city engineer. The specifications provide for a sub-foundation of 2 inches of sand and cinders mixed one to one and thoroughly rolled or tamped, the sub-grade having previously been rolled. Upon this base a 5-inch concrete foundation was laid, mixed 1:3:6. This was provided with expansion joints along each curb, around all manholes or other fixtures, down the center of the street if this should be more than 28 feet wide, and crosswise of the street every 40 feet; these expansion joints being from ¾ inch to 1 inch in width. The edges of the transverse expansion joints are protected with 2½x2½-inch steel angle irons, rolled with a corrugated or diamond surface to prevent being slippery; these angle irons being set so that their upper surfaces come flush with the wearing surface, and anchored to the concrete with anchor bolts. The joints extend the full depth of the concrete foundation and are completely filled from the bottom to within a half inch of the top of the finished pavement with asphalt poured into the joints at a temperature not lower than 300 degrees.

After the concrete base has been placed and before it has begun to set, a 1¾-inch wearing surface is placed, which is composed of 1 part Portland cement to 1½ parts of crushed rock, from which all dust has been removed; the crushed rock consisting of approximately 40 per cent of ¼-inch size, 20 per cent of ⅛-inch size and 15 per cent of 1/16-inch size, the balance of about

25 per cent being sand. The exact proportion of these materials, however, may be varied by the engineer in order to obtain as dense a mixture as possible. Crushed stone and cement are mixed dry and then wet to the proper consistency, deposited on the concrete and worked or floated to a uniform surface which it is specified shall be free from waves or honeycombs. The surface is then treated by drawing a tool similar to a garden rake both crosswise and lengthwise of the street so as to cut the surface into squares of 2½ inches on a side, the cuttings being about ½ inch deep.

The paving is then allowed to dry, when the entire surface is covered with a coat of asphaltic cement, heated to a temperature of not less than 300 degrees and poured or spread over the surface to a depth of about one-eighth of an inch, mops, brooms or squeegees being used for this purpose. On this is spread evenly a dressing of fine stone chips heated to at least 250 degrees, enough being used to cover the entire surface. When the asphalt is cold the road is ready for traffic, which rapidly wears in or wears away the chips.

Mr. J. G. Thorne, city engineer of Clinton, Iowa, gave some comparative figures on concrete pavement with bituminous surface and brick pavement before the 1914 meeting of the Iowa Engineering Society. The comparison was based on work done in Clinton in 1913, the contract price on the brick pavement being $1.80 per square yard, and the price of the concrete with bituminous surface being $1.18 per square yard.

The concrete pavement was a 1-2-4 mixture, the slabs uniformly 6 inches thick, and coated with ½ gallon of bitumen to the square yard.

"Owing to the inevitable tearing up of the streets we will assume that the life of any concrete base is only 40 years," says Mr. Thorne. "The estimated life of a surface for bituminous coated concrete pavements and brick pavements has been limited to the period during which it is believed that the surface can be economically kept in repair. In comparing the annual cost of these two types of pavement it must be assumed that the kind or the type of the pavement is selected with due regard to traffic conditions. It is also assumed that ordinary repairs will be made promptly and efficiently so as to keep the surface in a satisfactory condition at all times."

The comparison in the following table serves to show the relation in the annual cost per square yard between a low and a medium priced pavement.

TABLE I.

	Bituminous coated concrete paving.	Vitrified brick paving on concrete base.
First cost	$\frac{\$1.18}{40}$ $0.0295	$\frac{\$1.80}{40}$ $0.045
Life of base	40 yrs.	40 yrs.
Life of surface	5 yrs.	20 yrs.
Maintenance per sq. yd. per year	.01	......
Int. on original investment, 6 %	1.18×.06-.0708	1.80×.06-.108
Cost of renewing face	.15	1.25
Annuity required for replacement of surface, 4 pct	.0276	.042
Average annual cost	.1084	.15

Again referring to Mr. Thorne's paper, he continues:

"The above price of $1.18 for bituminous coated concrete and $1.80 per square yard for vitrified brick are the contract prices for paving in Clinton in 1913. The life of the surface has been assumed to be five years for bituminous coated concrete and twenty years for brick, at the end of which time the entire surface must be renewed In view of the fact that the bituminous coated surface is to be renewed every five years, I believe that 1 cent per square yard averaged over the whole contract is sufficient for ordinary repairs or patchwork. Barring accidents, tearing up, etc., it is safe to say that the brick will not need repairs in twenty years I know of certain streets in Clinton which were paved with brick on crushed rock base twenty years ago, and with the exception of trench replacements, the pavements have not received repairs of any kind. The cost of renewing the surface per square yard I have estimated for bituminous coated concrete at 15 cents and for brick, $1.25.

"Under the heading of annuity I have stated the sum that must be placed in a sinking fund each year, which with compound interest at 4 per cent will equal $0.15 in five years for bituminous coated concrete and $1.25 in twenty years for brick surface.

"The average annual cost, which is the sum of the maintenance, interest and replacements, shows $0.1084 for bituminous coated concrete and $0.15 for brick, a difference of $0.0416. In other words, the property owners or city must pay $0.04 per square yard per year for the privilege of having a brick surface instead of bituminous coated concrete surface; or the brick pavement at $1.80 per square yard, which is equal in annual cost to that of the bituminous coated concrete paving, would have to last about 100 years without repairs of any kind. In comparing these types of paving I have also given the brick the benefit of the doubt in regard to the repairs, as most authorities show that brick surfaces require some repairs.

"The bitumen used in coating concrete surfaces hould be a tar from which the volatile portions below 200° C. have been almost completely driven off by ıeating, thus giving the substance the proper consist-ency. One of the most important constituents is the free carbon (matter insoluble in carbon disulphide), as hat substance, in a tar, indicates the binding value. The bitumen may be obtained from the manufacture of either coke or illuminating gas. In making a set of specifications for this bitumen considerable latitude should be allowed, as it is doubtful if different batches of exactly the same proportions can be made."

The surfacing of a number of New England roads with bituminous materials is described by Mr. Herbert '. Poore in *Engineering and Contracting.* As a result of this work he arrives at the following conclusions:

(1) The finished thickness of the film should be as small as possible, consistent with a proper applica-tion of the bitumen and the grit. The advantage of a thin film is that when worn spots appear the slight difference in elevation between the base and the coated concrete is not noticeable under travel. With the de-velopment of a small number of weak spots it is not wise to at once make an immediate retreatment of the entire surface, as some portions would then have a dou-ble coat. A careful hand mopping of these spots with small quantities of bitumen will defer the day of gen-eral recoating.

(2) The application of two $\frac{1}{4}$-gallon coats with grit between gives a much better mixture of mineral and bitumen than one application of $\frac{1}{2}$ gallon. The former produces a surface of well mixed bitumen and grit which shows little tendency to roll or move about

on the concrete. This oftentimes happens with a ½ gallon coat in one application, notwithstanding a good bonding to the clean concrete surface.

(3) Much better results are obtained with power sprayers giving a uniform sheet of bitumen. Hand work, either with a single pressure nozzle or by hand pouring and sweeping, does not yield a uniform coat. The unevenness produced at the start is generally aggravated by traffic.

A warm, dry concrete tends to absorb some of the lighter oils from the tar bitumen and the concrete is often discolored to the depth of 1-16 inch. The application of a priming or filler coat of a thinner bituminous material has been tried, with the added object of keeping the tar oils from being absorbed from the first ¼- gallon coat. It is hoped in this way not only to obtain a closer bond, but to lengthen the life of the coating. The priming coat has been made fluid enough to flow cold and has been applied in such small quantity that the concrete takes it up after a few hours and presents a dry, tight surface for the first ¼-gallon coat of bitumen to adhere to. This results in better adhesion, especially if the concrete is slightly dusty, since the thin priming coat penetrates the dust to the concrete beneath.

In two cases the detailed cost data of making the original film treatment on 1-2-4 mixture concrete roads were as follows:

Case (1) A concrete road was covered with 0.2 gallon of Tarvia "B" per square yard, followed with 0.25 gallon of Tarvia "A" per square yard and covered with peastone at the rate of 1 cubic yard to 100 square yards of surface. A pressure distribution was used in applying the two coats of Tarvia. The treatment cost as shown below:

Cost of a Two-Coat Bituminous Surface on a Concrete Road.

	Per sq. yd.
Tarvia "B" at $0.105 per gal. applied, $0.02 gal. per sq. yd.	$0.021
Tarvia "A" at $0.12 per gal. applied, $0.25 gal. per sq. yd.	0.030
Peastone at $2.30 per cu. yd., including spreading, 1 cu. yd. peastone per 100 sq. yds. 1 sq. yd.	0.023
Total cost per sq. yd.	$0.074

Case (2) This treatment was applied to a concrete road and consisted of 0.5 gallon of Tarvia "A" per square yard covered with peastone. The cost is given as follows:

Cost of a One-Coat Bituminous Surface on a Concrete Road.

	Per gal.
Tarvia at side track	$0.08
Heating in tank car	0.02
Hauling 4 miles	0.006
Applying with steam sprayer	0.005
Cost of Tarvia "A" per gal.	$0.111
	Per sq. yd.
One-half gal. Tarvia "A" at $0.111	$0.055
Local peastone at $1.42 per cu. yd., 1 cu. yd. peastone per 100 sq. yds., 1 sq. yd.	0.0142
Total cost per sq. yd.	$0.0692

No charge is included for apparatus in either case, as this was loaned for the work. Ordinarily a slight increase in cost would be necessary for this item. The quantity of peastone required is variable, depending somewhat on the temperature prevailing during the work.

It is reported that there is much difficulty in making the bituminous material stick to the concrete. In Massachusetts success has been obtained by the following method: The concrete surface is swept as clean as possible, then sprinkled with water, and while still wet covered with Tarvia A, heated to 200° Fahr. and applied at a pressure of not less than 70 pounds per square inch, and at the rate of 1/4 gallon per square yard of surface. This is then covered with clean stone screenings (not exceeding 1/2 inch in diameter and from which the flour has been removed) spread at the rate of 0.015 tons per square yard of surface. This is again watered, and while still wet a second 1/4 gallon coating of tar is applied in the same manner as before, but covered with clean, gravelly sand, using 0.015 cubic yard per square yard of surface.

The application of tar on a wet surface is contrary to existing theories, but it has worked satisfactorily in this and some other instances.

Grouting for Wood Blocks. In a few instances cement grout has been used as a filler for wood block pavement with good results. In Cambridge, Mass., a 1:1 mixture of cement and sand was applied dry in two layers; afterward the pavement was wet with a hose and the grout broomed into the joints.

CHAPTER XVII.

Patented Concrete Pavements.

There are on the market and in successful use a er of patented concrete pavements, the patents ing either the combination of materials, the od of combining them, or the equipment by which ork is done. These pavements are described in hapter, and specifications for them are given in ppendix.

Granitoid and Granocrete. These two types of nent are patented under patents owned by the Ru- S. Blome Company, City Hall Square Building, go. They are both two-course pavements, in each ich a special feature is the scientifically correct rtioning and grading of the materials, especially surface, so that they will withstand the greatest nt of wear.

By reference to the specifications for Granitoid Granocrete pavements in the Appendix the careful er in which the combination of the concrete has adjusted to the wear will be at once apparent. It be noticed that while a liberal amount of cement d, it is used as a binder only, allowing the wear ffic to come upon the carefully graded hard aggre- of which the surface is composed. This not only s for the long life of the pavement, but also keeps m becoming slippery with wear.

Of the two types Granitoid has the thicker and ger top coat, and is intended for the heavier traffic,

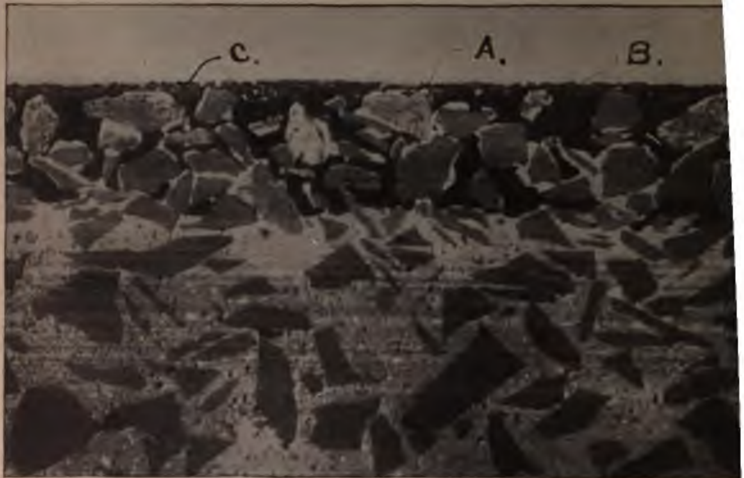
while Granocrete is designed mainly for residence streets, country roads and other districts of lighter wear.

The distinctive feature of Granitoid pavement is that it has the surface cut into blocks of about 4½x9 inches in size, with rectangular surfaces similar to paving blocks. This surfacing is done by a special method and apparatus covered by the Blome patents. Granocrete has an approximately smooth surface without markings.

Both forms of pavement have expansion joints at suitable intervals filled with a special composition covered by the patents.

Bitustone. This is the title given to a form of concrete pavement patented by Warren Brothers Company, Boston, Mass. It is described in detail by Mr. August E. Schutte in *Good Roads Magazine,* as follows:

"The Bitustone pavement is a pavement in which advantage is taken of the hardening of the Portland cement and of its rigid structure, when combined with the elastic and silencing effect of bitumen. Each individual particle of stone is held first by the Portland cement and then again by the bituminous cement. In constructing, there is first laid the bottom course, which is an ordinary concrete, preferably of the proportions of 1:3:6. Upon this bottom course is then laid a 1½-inch layer of practically uniform sized stone, coated with neat Portland cement in such a manner as to produce a bonding and keying effect between the individual stones, and a cementing effect at the points of contact, due to the Portland cement. This is easily produced by coating the stone in proportions of about



SECTIONAL VIEW OF BITUSTONE PAVEMENT

The light colored coating surrounding the stone marked "A" is Portland Cement; dark filler between the stone is the bituminous c pound, marked "B," and the coating of stone chips producing a ro surface is marked "C."

six parts of stone to one of Portland cement. The cement must not be so wet as to separate from the stone and run to the bottom, but must be of about 'medium consistency,' so that each stone will be thoroughly coated with neat Portland cement mortar, and when placed a double coating will be between each two stones at the exact point of contact. In that way is produced about an inch and a half of a course which I prefer to call the bonding course, for it serves to bond the bituminous cement to the stone, prevents its displacement, provides a surface coating of bitumen which is thoroughly keyed into the concrete bonding layer, and produces resiliency and durability by avoiding all abrasions and breaking loose of the aggregate forming the bonding course. It is understood that this bonding course forms a reticulated, mesh-like, vesicular, porous structure, into which the hot bitumen, which is poured upon and into this layer, enters, and adhering to the Portland cement, holds the particles of stone by its adhesion and cohesion. Thus there is produced in this pavement a combination of the entire strength and rigidity that can be obtained from Portland cement, combined with the strength, non-slipperiness and resistance to abrasion of the best bituminous macadam, and at the same time there is produced a pavement in which the wearing surface and foundation are one, which is rigid, and which can be laid on any sort of foundation without any special preparation.

"The main advantage of this pavement is its inability to be shoved and displaced. With its 'foolproofness' and possibility of being laid with unskilled labor, and with practically no machinery, barring perhaps a concrete mixer and ordinary bitumen kettle, the advantage can be particularly appreciated by those who have attempted to lay country roads with complicated machinery, with its attending delays on account of break-downs, lack of fuel, water, etc."

Dolaway Pavement. The patents on this pavement are controlled by the Dolarway Paving Company, Whitehall Building, New York.

This pavement was first used at Ann Arbor, Mich., in 1909, with 1,883 square yards laid, followed by 18,000 yards in 1910 and 64,000 in 1911, and in the spring of 1912 there were petitions on file for 140,000 additional square yards. This pavement is practically a concrete pavement covered with a bituminous mate-

rial. The requirements for the concrete at Ann Arbor are somewhat unique, as quoted herewith:

"One standard sack of cement shall be used for each square yard of pavement, and upon the completion of the pavement, if it shall be shown that less cement has been used than specified, the value thereof shall be deducted from any money due the contractor, and the contractor shall furnish to the Board of Public Works

Section Cut from Dolarway Pavement.

a sworn statement of the total quantity of cement usec Within 30 minutes after the concrete is placed it shal be struck off with a templet approved by the enginee until flush with the running boards, and as soon there after as practicable be trowelled to a true surface an(be broomed as directed. An expansion joint 1 incl wide shall be left at each curb, and an expansion joint about 1-2 inch wide shall be left every 25 feet transversely of the street."

After the concrete has become thoroughly set and dry a thin coating of Dolarway bitumen, about 1-2 gallon per square yard, is applied at a temperature of about 200 degrees F., and before the bitumen applied has become hard there is spread over the entire surface a uniform layer of torpedo sand, the transverse joints being filled with the bitumen and sand flush with the surface of the pavement. The thickness of the bitumen and sand ranges from 1-4 to 3-8 of an inch. It is claimed for this pavement that the concrete serves really as the pavement, and that the surface coating of bitumen and sand protects the concrete from wear, so preventing the formation of dust and giving practically an asphalt pavement so far as use is concerned.

The cost of the pavement varies, of course, according to localities and the cost of materials, but it is stated that if there be added to the cost of concrete 25 to 35 cents per square yard, the same being the cost of the bitumen and the royalty charged by the company, the total cost of the pavement can be obtained. It is stated also that the pavement can be resurfaced at an approximate cost of 10 cents per square yard.

Hassam Pavement. The following description of the Hassam pavement is furnished by Mr. Harold 'arker, vice-president of the Hassam Paving Comany, Worcester, Mass.:

"The so-called Hassam pavement is in its present orm the perfected result of many experiments made y W. S. Hassam while he was superintendent of streets of Worcester, Mass., and since, after it was found that the method put into practice by him as an official had a large commercial value. It was found in practice that ordinary mixed concrete used as a foundation for brick or stone block pavements failed to meet all the requirements. It was found, for example, that it was difficult to obtain a perfectly uniform surface on which to place brick or stone blocks and have it at the same time of uniform density or with a uniform distribution of ingredients.

"When the concrete is laid for foundations of piers or buildings and the mass is of great depth, this fact is not of great importance; but when only a thin layer on the sub-grade of a road or street is required, it became of serious moment. It will be recognized that owing to the different specific gravity of the various materials composing the concrete mass, there will be a separation of the parts before the cement is set. This is practically observed when a batch of concrete is transported either in a wheelbarrow or cart; the shaking of the mass, even when run over a good roadway or plank, settles the mineral aggregate to the bottom and leaves the cement mortar on top. The dumping of a barrow or cart-load still further disturbs the relation between them. Each load that is dumped is more or less different from all others and there is greater density in some portions of each load than in other portions, so that as a matter of fact it will be found on examination of concrete laid on the sub-grade of a road or street that masses of stone with comparatively small amounts of cement and sand will result, and in others cement and sand and very little rock; in short, no two adjoining sections will have the same amount of the specified ingredients. This condition is but little helped by ram-

Section of Hassam Pavement.

ming or tamping. The practical result is that two unsatisfactory conditions are manifest, viz.: that the surfact of the cement foundation is uneven, and the sustaining strength of the concrete is never the same in all parts of the road.

"These conditions led to a series of experiments in order to obtain for stone block, brick or wood block pavement an even foundation of uniform strength, which would secure a smooth final surface and one which would hold its shape indefinitely. It was found after many trials that the most satisfactory, if not, indeed, the only way to obtain all the necessary characteristics for such a base was as follows: Broken stone sufficiently tough to withstand the weight of a 10-ton roller when run over it enough to thoroughly compact it, is placed upon a properly prepared sub-grade and rolled until thoroughly compacted. This stone should be of cubical form and not less than 2 inches in its largest dimensions, and should be so carefully placed that after rolling it should present a perfectly uniform cross-section, rough because of the large size of the individual stones, but uniform in shape both longitudinally and laterally. The voids between the stones are then reduced to a minimum, and a cement grout composed of 1 part hydraulic cement to 2 or more parts of sand and sufficient water to secure an easy flow, is then distributed evenly over the stone placed as above described. This can best be done by a grouting machine invented for the purpose.

"Before the grout has begun to set the whole is thoroughly rolled again. This is done to force the grout into every void and to drive out any air, making the whole a monolith. This process compresses the concrete

from 15 to 25 per cent compared to ordinary mixed and tamped concrete; in other words, the same amount of material will occupy from 15 to 25 per cent less space; moreover, every square yard of surface will have exactly the same amount of stone under it, with an exactly uniform amount of cement and sand. Any pavement laid in such a foundation never gets out of surface, except by the wearing away of the surface itself; depressions in the road never appear by reason of settlement or lack of uniformity of the foundation—all parts are of equal strength.

"The foundation laid as I have described was found to be so uniform in shape and so indestructible in character that where traffic was not too severe, it was adopted as a completed road and many hundreds of thousands of yards have been so laid with entire satisfaction, the only criticism possible being that surface cracks appear unless great care is taken to protect the top until well set. Such cracks do not reduce the strength of the road, but they are unsightly and sometimes chip on the edges. So-called expansion joints will not prevent the occurrence of such cracks, because the cracks are the result of contraction and not expansion. This is the difference between the foundation I have described and the same method used as a finished road, viz.: that the distribution of the grout should be so made that the actual wear of wheels and horses' feet should come upon the stone and not on the grout. This can be done by brushing with wire or other coarse broom before the cement is set, the brushing to be done from side to side and not longitudinally. A smoother top can be obtained, of course, by flushing the surface with a richer grout.

"A road built in this way is, of course, somewhat dusty, and more or less noisy; it is also rigid and hard on horses' feet, but not slippery. In order to overcome these objections, experiments were made in using tar or other bituminous compound to cover the surface. These experiments began as long ago as 1906 with ordinary gas house tar, put on with pails and brooms. It was found that this tar so applied stripped off and at the end of a year of fairly heavy and varied traffic most of it had disappeared. Since then many trials have been made, and, as a result, my own view is that the following produces the best road surface. The concrete road made as I have outlined must be thoroughly cleaned, washed if possible so that no dirt or foreign matter remains in it. While the surface is still slightly damp a coal gas or water gas tar, refined, but with some of the volatile oils still remaining, should be applied to the surface by means of a machine that will force it onto the road under pressure of 70 to 80 pounds to the square inch with the nozzles of the machine within six inches of the road. This application should not exceed ¼ gallon to the square yard. Immediately after this application is made it should be evenly covered with stone chips and rolled with a light steam roller. After brooming off the loose chips another application of heavier tar, or preferably asphalt, also under pressure, and a little more in quantity (from ¼ to ⅜ gallon), this layer also to be immediately covered with stone chips or coarse sand, and again rolled."

Vibrolithic Concrete Pavement. This name is a term applied by R. C. Stubbs, a contracting engineer of Dallas, Texas, to a class of pavement put down in various parts of the country, and described by him in a paper before the American Concrete Institute. The distinctive feature of this method is the use of a vibrator on the surface of a concrete pavement to bring the concrete to a dense and even texture.

The plan followed by Mr. Stubbs is to prepare the sub-grade as for any other pavement, after which the aggregate is hauled in and stored on the sub-grade. A traction concrete mixer is then brought in, with charg-

Laying Vibrolithic Pavement.

ing bucket to receive the material and a chute to discharge the concrete.

Concrete is composed of one part Portland cement and five parts aggregate—sharp sand and gravel—the portion passing a ¼-inch screen not to exceed 40 per cent, nor be less than 33 per cent, using as much water in mixing as the mass will retain without draining after depositing. The concrete comes directly along the chute to the street and is immediately raked to approximate grade.

After an advance of a few feet, the surface is brought to a float finish by means of long-handled floats. Immediately upon this surface there is thrown a coating of crushed granite, graded from ⅝ to 1¼ inches. This stone is applied until surplus matrix has been taken up.

This surface is then ready for vibration. The first part of this operation is to place platforms along or across the street, made up of ⅝x4 inch strips cleated ¼ inch apart. Each platform is 20 inches wide and as long as desired, cleats projecting 1 inch along one side, the forward platform cleat projection lapping back onto another platform. When two or three platforms have been placed, a vibrator mounted on rollers is rolled onto the first platform and passing along from one to the other as they are put to grade, and the concrete is brought to a very high state of density.

The construction of these vibrators was not gone into in detail by Mr. Stubbs, as he states that any device producing a vibration will answer the purpose, but the illustrations will give some idea of the type used by him. One of these he describes as simply a high-speed single-cylinder 5-horsepower motor with out-of-balance fly wheel. He states that thickness of mass, area covered or affected, thickness of platform boards, weight of vibrator, rate of vibration, and force of blow delivered, must all be taken into consideration in order to secure best results.

As the work progresses, the platforms are brought forward and the granite surface of street is immediately covered with sharp sand and wetted. This is the first operation and completes a stone 6 inches thick, composed of 1 to 5 concrete, top 1 to 1½ inches loaded with stone of high abrasive resistance—a street with un-equaled load-carrying capacity. The surface being composed of granite, all parts have an equal resistance to abrasion. The granite being forced into the concrete with vibration cannot be gotten out, but must wear out.

The vibrators being mechanical, they can be relied upon to treat all parts alike, the operator's duty being simply to roll them over platforms to insure a concrete of equal and even texture. This evenness of texture gives uniform power to overcome internal stresses. High density means greater strength and a reduction of contraction and expansion factor from .0000065 to .0000032.

Two or three days later the sand is swept off the surface into the gutter with stiff wire brooms, and ¼-inch Tarvia A is poured at a temperature of 150 degrees F. and leveled with rubber rakes. Immediately behind the levelers a coating of hard stone ¼ to ⅜ inch is spread in sufficient quantity to thoroughly coat the pitch. Upon this is spread the sharp sand that has been swept into the gutter. The surface is then rolled with a 500-pound hand roller and street is held until concrete is 7 days old and then opened to traffic.

The object in placing this coat so soon is to retain the original moisture in the concrete, that the process of hydration may be complete. Pitch may not adhere well to a moist mortar, but takes a firm hold on the granite surface.

After 30 days' traffic the surface irons down smooth, the small stone protects the pitch, while the sand fills the interstices, producing a very tough surface which will show a thickness of about ½ inch.

"I provide for contraction joints only," says Mr. Stubbs; "that is, I do not use bituminous joints to take concrete laid on the sub-grade of a road or street that masses of stone with comparatively small amounts of cement and sand will result, and in others cement and sand and very little rock; in short, no two adjoining sections will have the same amount of the specified ingredients. This condition is but little helped by ram-

Section of Hassam Pavement.

ming or tamping. The practical result is that two unsatisfactory conditions are manifest, viz.: that the surfact of the cement foundation is uneven, and the sustaining strength of the concrete is never the same in all parts of the road.

"These conditions led to a series of experiments in order to obtain for stone block, brick or wood block pavement an even foundation of uniform strength, which would secure a smooth final surface and one which would hold its shape indefinitely. It was found after many trials that the most satisfactory, if not, indeed, the only way to obtain all the necessary characteristics for such a base was as follows: Broken stone sufficiently tough to withstand the weight of a 10-ton roller when run over it enough to thoroughly compact it, is placed upon a properly prepared sub-grade and rolled until thoroughly compacted. This stone should be of cubical form and not less than 2 inches in its largest dimensions, and should be so carefully placed that after rolling it should present a perfectly uniform cross-section, rough because of the large size of the individual stones, but uniform in shape both longitudinally and laterally. The voids between the stones are then reduced to a minimum, and a cement grout composed of 1 part hydraulic cement to 2 or more parts of sand and sufficient water to secure an easy flow, is then distributed evenly over the stone placed as above described. This can best be done by a grouting machine invented for the purpose.

"Before the grout has begun to set the whole is thoroughly rolled again. This is done to force the grout into every void and to drive out any air, making the whole a monolith. This process compresses the concrete

CHAPTER XVIII.

Some Tests of Concrete as a Roadway Material.

The most valuable tests of road materials which have recently been made have been those carried on by the Department of Public Works of the City of Detroit. The value of these tests consists in the fact that they were made with actual sections of pavement under an approximate duplication of traffic conditions rather than being mere arbitrary tests of materials.

For the purpose of these tests a device called a paving determinator was made by Mr. J. C. McCabe, city boiler inspector of Detroit. This device runs over a circular track, and in the original test this was composed of eight different sections of pavement.

The whole track was underlaid with 8 inches of concrete, the foundation for all experimental pavements. The block pavements were put down under Detroit specifications. All the block and brick were cushioned on 2 inches of sand, which had previously been thoroughly compacted with hand tamps. The spaces between the cedar block were filled in with gravel, and the brick and granite were well grouted. The concrete was laid 6 inches thick of a mixture of 1:1½:3, using washed sand and pebbles, according to the Wayne county specifications. The samples were not disturbed for 60 days, when the test was begun. This test showed the concrete section to have by far the greater resistance to wear.

The determinator consists essentially of an upright column fitted with a large gear, by means of which the shafts bearing the testing apparatus are made to revolve about the column in a horizontal position, at a rate of speed governed by the rapidity with which the gasoline engine furnishing motive power is run. The engine is of 6 horsepower, and speeds varying at the wheels from 3 miles to 12 miles per hour are developed.

The double wheels at the extreme ends of the horizontal shafts weigh 1,400 pounds each, and by means of a simple connection the exterior discs may be removed and similar discs of varying width, comparable to the widths of different tires, may be substituted.

One of the most ingenious features of the apparatus is the fidelity with which the effect of horse-drawn vehicle traffic is simulated. Between the outside disc, which represents the wheel of a wagon, and the inside ribbed disc, which encloses the mechanism, are placed five plungers, each bearing on its end a plate shaped like the bottom of a horse's hoof. These plates are furnished with four steel points similar in appearance to the calks worn by draft horses on their shoes in winter. As the wheel revolves the hoof-shaped plate strikes the pavement at a pressure of 150 pounds, produced by a cam geared to the horizontal shaft. As soon as the hoof-shaped plate has passed the point of contact it is released and a spring at the back reproduces the ankle motion of a walking horse.

In order to avoid making a single track for each wheel, which would result in all the wear coming on a definite circle drawn upon the pavements under test, Mr. McCabe has installed a worm gear, geared to a crank attached to the horizontal shaft. As the ap-


THE PAVING DETERMINATOR
PROPERTY OF CITY OF DETROIT, MICH. EXHIBITED BY
UNIVERSAL PORTLAND CEMENT CO.
THE PAVING DETERMINATOR
UNIVERSAL PORTLAND CEMENT CO.

ratus revolves one of the wheels is at the outside the path to be tested and the other at the inside. the wheels travel around the crank draws one in ward the center and pushes the other out from the ter, with the result that at the end of a given num- of revolutions the wheels have changed places as regards their distance from the center.

The original test was made at 9 revolutions per minute about the circle, which gave a speed of 6.96 miles per hour at the outside and a speed of 5.51 miles per hour at the inside of the track.

Strangely enough, perhaps, the first section of pavement to give way was the granite block, which very soon loosened up in the grouting under the impact of the wheels. The failure of the granite was passed along to the next section, which was creosote block, and under this pavement the sand cushion caved considerably, causing the pavement to sink in the track which was covered by the wheels. The next brick section (Section 4), showed considerable wear and chipping. The cedar blocks were severely mashed and forced down into the sand. The brick section next in the path of the improvised traffic was completely destroyed, and part of this section had to be replaced before the test could be continued, because the destruction had gone so far as to interfere with the progress of the mechanism. The next section, also brick (Section 7), showed severe wear, and not all of this was due to the failure of the section before it, because where the worst break came did not follow the worst break in the preceding section. Next in line was the concrete section. The only bad break in the concrete was contiguous to a very severe break in the preceding brick section, where the impact of the heavy wheel, coming from the broken brick pavement, could not help but do considerable damage. The abrasion of the concrete surface was regular and not more than ¼ inch, while the granite was worn down more than 1 inch, and some of the brick fully 2 inches. The brick section, which had to be replaced while the test continued, was down more than 3 inches.

This paving determinator was brought by the Universal Portland Cement Company to the Chicago Cement Show in January, 1913, and a number of sections of pavement were tested at that time, the specimens later being shipped to Detroit and the tests continued there.

All concrete sections were of the same size, approximately 3 feet 6 inches wide and 4 inches thick, reinforced at the center to prevent breaking in handling, with American Steel & Wire Company's triangle mesh, style No. 28. Ten sections with an 8-inch space between them formed a circular ring having an outside radius of 11 feet 3 inches.

The concrete sections were all made in the week of Nov. 19 to 26, 1912, using Universal Portland cement, clean, coarse sand and a coarse aggregate, either screened, washed gravel, crushed limestone or crushed granite. The concrete was well mixed by hand with sufficient water to produce a medium wet consistency, lightly tamped into the forms, the surface struck off with a straight-edge, finished with a steel trowel and then slightly roughened by brushing with an ordinary broom. The sections were cast indoors where the temperature varied during the time they were curing, from close to freezing, to about 70 degrees F. All sections were kept well sprinkled with water for three days, and between Nov. 29 and Jan. 16 were sprinkled on two different occasions. The description of sections follows:

Section No. 1. 1 part cement, 1½ parts sand and 3 parts ¼ to 1½ inch screened, washed gravel; one edge of section protected with Baker metal plate.

Section No. 2. 1 part cement, 1½ parts sand, and 3 parts of a mixture composed of 4 parts 1 to 1½ inch and 3 parts ¼ to 1 inch crushed Wisconsin granite.

No. 3. 1 part cement, 2½ parts sand and 5 parts ¼ to 1½ inch screened washed gravel.

No. 4. 1 part cement, 1½ parts sand and 3 parts ¼ to 1 inch crushed limestone.

No. 5. 1 part cement, 2 parts sand and 4 parts ¼ to 1½ inch screened washed gravel, one edge of section protected with Baker metal plate.

No. 6. 1 part cement, 2 parts sand and 3 parts ¼ to 1½ inch screened washed gravel.

No. 7. Wearing surface 2 inches thick, 1 part cement, 2 parts clean, coarse sand; base a 1:3:5 gravel concrete.

No. 8. Wearing surface 2 inches thick, 1 part cement, 2 parts of a mixture composed of 1 part ¼ inch granite screenings and 2 parts ¼ to ¾ inch crushed granite.

No. 9. 1 part cement, 1½ parts sand and 3 parts ¼ to 1½ inch crushed limestone.

No. 10. 1 part cement, 2 parts sand and 4 parts ¼ to 1½ inch crushed limestone.

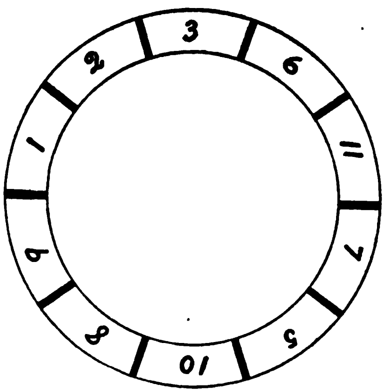
No. 11. 1 part cement, 2 parts sand and 4 parts crushed granite same as used in section No. 2.

At the cement show the machine ran for a total of a little over 63 hours, each wheel in that time making 18,978 complete revolutions, the speed of the wheels varying from 3.06 miles per hour when traveling the inner circle of the path, up to a speed of 3.86 miles per hour in traveling the outer circle.

The work in Detroit in continuing the test was in charge of a representative of the Inspection Bureau of the Universal Portland Cement Company. The original 8-inch concrete floor put down in the eastern yards of the Detroit Department of Public Works to

receive the determinator, was used for a fo
On this was placed a 2½-inch bed of cement-s
tar, in a mixture of 1:1½, to bring the test se
to the proper level. Over this was run ¼
cement grout, in which the slabs to be test
bedded. The concrete pavement sections put
Detroit on this mortar and grout foundation
ranged as shown in the accompanying diag
numbers corresponding to the numbers give
test specimens above.

Between sections there was a joint 8 incl
made of 4-inch creosoted wood block put in



Location of Slabs Under Determinator.

pitch and gravel. Soft steel plates were used
edges of the concrete slabs. At the outset the
minator was run at 8½ revolutions per minute
gave a speed of 6.6 miles per hour at the outer
the track, with a speed of 5.2 miles per hour
inner circumference, or an average speed of 5.

per hour. This speed was maintained for 5,700 revolutions of each of the wheels of the determinator, and the pounding was so great as not fairly to represent vehicle traffic on a pavement.

Before proceeding with the test in Detroit, three of the five plungers on each wheel were removed, leaving two to a wheel, which seemed to be fairly comparable to ordinary vehicle traffic with two horses and eight hoofs to four wheels.

After the 5,700 revolutions had been made, the speed was reduced to 6½ revolutions per minute or 5 miles per hour at the outer circumference, 4 miles per hour on the inside, or an average of 4.5 miles. This speed was maintained until a total of 20,400 revolutions had been made, so that those slabs which had been previously tested in Chicago underwent a total wear of nearly 40,000 revolutions.

In this connection it may be remembered that in the first test with the paving determinator at Detroit, under the direction of the Department of Public Works, some of the brick pavement sections had practically gone to pieces when 6,000 revolutions had been made.

Before the machine was started in Detroit, very careful level readings were taken on each one of the slabs in the track, using an architect's level reading to thousandths of a foot. Fifteen readings on each slab were taken within the wheel track, and one at each of the four corners of each slab outside the wheel track. There were other readings after 12,400 revolutions had been made, and final reading at the completion of the test, after 20,400 revolutions. Final readings showed wear on the various slabs as follows:

Slab No.	Average wear after 20,400 rev. (given in inches)
1	0.19
2	0.11
3	1.38
5	1.77
6	0.24
7	0.26
8	0.18
9	0.13
10	0.44
11	0.16

In a resumé of the observations made after the test the Inspection Bureau outlines the following:

Sections Nos. 3, 10 and 11 had had no wear previous to the test in Detroit. Section No. 5 was somewhat rough from previous wear when it was put down in Detroit.

Sections Nos. 3 and 5 showed the concrete to be unsatisfactory for wearing surfaces. Section No. 3 was a mixture of 1 part cement, 2½ parts sand, and 5 parts gravel, screened, washed and graded from ¼ to 1½ inches. Section No. 5 was a mixture of 1 part cement, 2 parts sand, 4 parts ¼ to 1½ inches screened, washed gravel. Both of these sections were worn down to the reinforcing metal and Section No. 5 was worn so badly after 12,000 revolutions in Detroit, or a total of 31,000 revolutions, that it was necessary to use gravel to help the wheels of the determinator over this slab.

Section No. 2, which is one of those also used in Chicago, was still in perfect condition at the end of the test. This section is made of 1 part cement, 1½ parts sand, and 3 parts of a mixture composed of 4 parts 1-inch to 1½-inch and 3 parts ¼-inch to 1-inch crushed Wisconsin granite. This is the identical mixture, although not the same aggregate, used by the County Road Commissioners in the roads of Wayne County.

Section No. 8, a slab which was made in two courses having a wearing surface 2 inches thick, or 1 part cement and 2 parts of a mixture composed of 1 part ¼-inch granite screenings and 2 parts ¼ to ¾-inch crushed granite, was not so satisfactory as section No. 2. The larger aggregate used in the one-course pavement therefore seemed to be better for heavy traffic.

Section No. 9, made of a mixture of 1 part cement, 1½ parts sand and 3 parts 1½-inch crushed limestone, wore very smoothly, the wear of the stone being uniform with that of the mortar which bound it. The next leaner mixture of the same materials, however, did not prove to be satisfactory. This is shown by section No. 10, made of a mixture of 1:2:4 cement, sand and crushed limestone, in which the stone wore roughly and unevenly and indicated that a continuation of the test would render it unsatisfactory. Section No. 1 and section No. 6 wore uniformly, but with a slightly rough surface which, however, seems to be rather advantageous than otherwise, because it gives a good foothold.

Section No. 1 is practically identical with the mixture now used in Wayne county. It consists of 1 part cement, 1½ parts sand and 3 parts ¼ to 1½-inch screened washed gravel. One edge of this section was protected with Baker metal plate. Section No. 6, similar to section No. 1, though rather more lean, was made of 1 part cement, 2 parts sand and 3 parts screened washed gravel, of the same size as in section No. 1. Section No. 7, having a wearing surface 2 inches thick of 1:2 mortar in which clean, coarse sand is used, with a base consisting of a 1:3:5 mixture of gravel concrete, wore very uniformly.

Section No. 11, consisting of a mixture cement, 2 parts sand and 4 parts crushe answering the same description as that used proved to be satisfactory by showing even we rough surface for good foothold. The object mixture lies in the difficulty of obtaining surface without depressions, which is a most requirement. The 1:2:4 mixture worked that although the slabs were made under conditions, it was impossible to finish sectio smoothly and the hammering caused by u resulted in a depression at one corner.

The tests have demonstrated that a sa wearing surface, under the most severe traf tions, can be obtained with a 1:1½:3 mixtu ment, clean, coarse sand and coarse aggregat ing of well graded, screened, washed gravel, o crushed limestone, ranging in size from ¼ to

A 1:2:4 mixture with either of these mat mixtures containing less cement, will not v the impact and abrasion of traffic in a degr comparable to the richer mixture.

A 1:2 mortar, made with clean, coarse, we sand, will withstand the effect of heavy traf factorily, although the wear is greater than on containing coarser material.

Gravel containing a small percentage of so is objectionable because the soft stones give p the wear to start. For this reason crushed st taining material of uniform hardness, show value to gravel, consisting of harder partic with a small proportion of soft pebbles.

Crushed Wisconsin granite, graded in sizes from ¼ to 1½ inches, was, unquestionably, the best material used for coarse aggregate in the slabs tested.

Unevenness of surface finish, due to poor workmanship, causes pounding under heavy traffic and develops holes in the pavement which, if smooth, would withstand the same traffic perfectly for an indefinite period.

Severe Test on Concrete Base. Because of complaints to the effect that the concrete base being laid on the new California state highways is not sufficiently thick to make it permanent, the highway commission decided to make a test, and this was done on January 22, 1912, just north of Fresno. A report of the test was submitted by J. B. Woodson, sixth division engineer, to A. B. Fletcher, chief engineer of highway construction.

According to the report of the Fresno office on the test made on January 22, the concrete at that point was laid on December 19, and was therefore 35 days old when tested. On examining a piece of fractured pavement it was still moist for the full thickness, as the weather at this time of the year is not conducive to rapid drying. The concrete would therefore probably have stood a greater strain if thoroughly dry.

A trench 2 feet wide and 4 feet long was dug underneath the pavement, 12 inches from the edge, leaving the concrete over this trench without any support.

The rear wheel of a 10-ton road roller was then run over this concrete slab in many positions.

When the wheel was run over the pavement 12 inches from the edge there was no effect on the concrete. When it was run over the pavement 6 inches from the edge, there was still no effect.

On the third test, the wheel was run ove crete 6 inches from the edge and stopped in t of that portion of the concrete directly over th also without any effect. When the edge of tl was run over the span, flush with the edge of ment, there was a slight spring.

The fifth test consisted of running the wl with the edge of the pavement, but also over a wood 2 inches thick, 4 inches wide and 8 inc placed 12 inches from the edge. There wa noticeable spring as the wheel passed, but no fr the pavement.

The test that finally fractured the conc sisted of running the wheel over the span flush pavement and over the block that was place span, 6 inches from the edge. The concrete hold on this test.

Notwithstanding the fact that the concrete moist, the local division office reported that th seemed to be all that could be desired, as the tration on the 4-inch block was almost 3½ tons, 1,666 or two-thirds of a ton to the square inch unsupported base.

The local division engineer made the f conclusions as to the durability of the road, i port:

"In view of the fact that the concrete did ture when tested 12 inches from the unsupport with the above concentrated load, and will n called upon to bear such a load under actual tra ditions, I believe we are justified in stating 4-inch concrete base properly constructed as th will stand any reasonable loads."

CHAPTER XIX.

How to Promote the Construction of Concrete Roads.

The development of concrete roads has been one of such rapid progress that it has been impossible for the general public to keep up with it. On this account there are some localities where considerable educational and promotional work are required in order to secure such roads, and it is for the help of such localities that this chapter is written.

It has been the experience of such localities that where a concrete road was once secured, even in the face of opposition from a considerable number of taxpayers, promotional work, so far as developing an interest in concrete is concerned, has had to be gone through with but once. Such a road, unless by some unfortunate circumstance the construction has been deplorably faulty, has made many friends for itself and has been the occasion of demands from nearby localities for other roads of the same type.

The person who sets out to promote a concrete road, or indeed any kind of a road, must first thoroughly familiarize himself with the laws under which he must work. He must know, for instance, what state moneys are available for highway construction in his locality and under what conditions they can be secured. He must also understand thoroughly his county, township and municipal regulations, as well as the financial limit for this purpose. It is perhaps unnecessary to say that he should go on the theory that all possible money should be spent for this purpose

which the laws of his state and the various otl
erning bodies under which he must work will
There are no instances on record where too much
has been appropriated for this most importan
The tendency is rather in the other direction, so
is difficult to find any locality where a sum of
sufficient for its needs has been appropriated.

The man who is promoting concrete roads n
course, have at his command the various gene
vantages of hard surface roads and must be
present his arguments in a convincing manner.
scarcely necessary at this time to go into thes
ments in detail, as a great many of them are :
of common knowledge to road builders, while t
cific arguments in favor of concrete roads are g
the first chapter of this book.

From the experience of many road builder
ever, it might be well to suggest a refutation of
one or two arguments which are frequently l
forth against permanent roads of any kind. (
these, and one most frequently heard, is that tl
under consideration does not carry sufficient tr
justify the expenditure which a permanent road
sitates. It has been proven time and again tl
reason of little traffic has not been because of t
of traffic possibilities, but because the roads have l
such bad condition that a use of them was unde
and at some seasons of the year indeed impossibl
one of these roads in first-class condition, with
surface, and the travel will soon jump up sufficie
justify the expenditure. Such a road may cor
number of farms with one of the main arteries
nearest town. It is over this road that these f

must deliver all their produce to market. It may possibly be that at the very time when market prices are the highest for such classes of produce, the road is in an impassable condition and the farmer is obliged to sacrifice a part of his profit because of highway conditions. He stays at home, and the road is not used; but this is not because the traffic was not there, but because the road was incapable of carrying it.

The situation is very similar to that of a family which considers that it has no use for a telephone in the house; but once put it in and it will be found that it will be used several times daily, saving a great many steps and proving itself a source of convenience, so that no member of the family would be satisfied to have it taken out. This is one of the things which a telephone company can rely upon as a practical certainty. If this were not so, telephone rates would necessarily be much higher than they are, to cover the cost of making installations for a short time and to provide for the increased sales expense which the continual loss of customers in any business necessarily entails. As it is, however, no sales ability is needed to hold telephone customers when once the service is installed, and each instrument which is put in helps to make the whole system more valuable and more desirable.

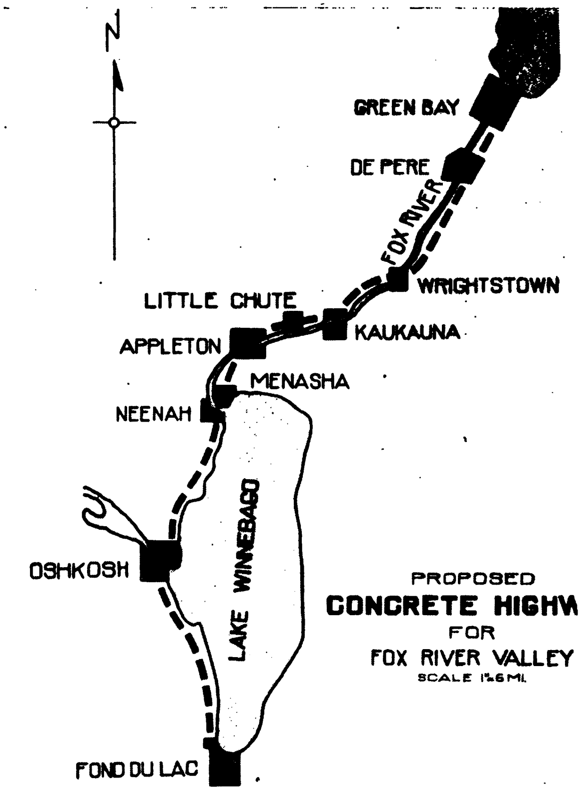
So it is with concrete roads and pavements; and for this reason, however much may be said against the system of building short detached sections of road, the plan of planting "seedling miles" of concrete roadway in various sections has some things in its favor.

It must be remembered, too, that in constructing permanent roads which are to last and give service throughout a long period of years, the cost should be equalized over at least a part of that term rather than being paid entirely by the pr ration. This means that a series of bonds issued to cover the cost, this series maturing during the life of the proposed improveme cannot be construed in any way as throwing ent burden upon future generations, but simp that each generation shall pay for the imp which it enjoys. It is vastly different from bond issue for merely temporary improveme will not last in many cases until the bonds tured. Instances have been known where bo of this kind have piled up on each other so payers have had to pay for two or three succe strutions from which they derived no benefit. is justified in going before the taxpayers with sition of this kind; but, on the other hand, the to them with a clear conscience and present t proposition for issuing a bond issue for a pe concrete road, the bond issue covering the e life of the improvement in such manner that e that year's portion of the cost and maintenanc road would be paid for.

It will have to be admitted that the m getting any considerable number of people to a bond issue for road construction will many t a matter of education. They have been so acc to seeing roads constructed in a temporary ma that they go to pieces in a year or two, and th cost has to be gone over again. The people United States are, however, more able at the time than ever before to build permanently rath simply to construct in a makeshift way for te needs. It is estimated by the Office of Public Roads at Washington that we are raising at the present time for road and bridge purposes approximately $180,000,000 annually. In twenty years, at this rate, we will have raised $3,600,000,000, which it is estimated is a sum large enough, if expended systematically by competent road builders, to give us 300,000 to 350,000 miles of permanent roads; and it is further stated that this, in addition to the present improved milage, would accommodate 90 per cent of the traffic.

In view of these facts, it is deplorable to think that we have been paying out this money every year and yet have so little to show for it. The reason is that so much of this money has had to go for maintenance and repair, as well as for the entire reconstruction of roads which have been built of only temporary materials. A thing which must be eternally preached to the people at large is the gospel of permanent construction, so that when once a mile of roadway is put down, no more thought need be given to it, aside from possibly a few dollars for minor repairs, and that all money appropriated can be spent on new work.

Another element which must not be forgotten in a campaign for the construction of concrete roads is the very active and important part which women are now taking in all public movements. Not so many years ago it would probably have been considered very largely a waste of time to talk on good roads before a woman's club. Anyone who is abreast of the times will realize that at present this is not so. Not only is it worth while to solicit the support of women, both as individuals and in their organizations, but it has also been found in some localities that permanent roads would probably never have been put through, in so short a time as has been the case, wer for the active propaganda which has been ca by women's clubs and other organizations of



Map Used in Promoting the Construction of a Concrete

It is said that woman's work is never done. times a day she cooks, washes the dishes, and se house in order, only to have the same work to do again at the next regular meal. At times her nerves become "frazzled" and she thinks the whole thing is futile, and she longs for dishes which will stay washed and a house which will right itself automatically. She longs to do things that will count for something and will "stay done," and on this account the permanence of the concrete road appeals to her.

While all the work which is done, if it is done intelligently, will benefit the construction of concrete roads as a whole, much more can be accomplished if promotional work be devoted towards securing the construction of some one particular piece of work. Take it, for instance, in a territory where there is little enthusiasm for good roads in general, and possibly a more or less pronounced hostility to concrete roads in particular. The way to accomplish results in the shortest space of time and with the least expenditure of effort is to map out some particularly attractive piece of road and center all the effort upon it. For this purpose a piece of road should be selected on which the benefits of improvements will be recognized most readily. To be specific, we might mention the road shown on the accompaying diagram, connecting Fond du Lac with Green Bay and running through a number of other cities on the way. It might be mentioned that this diagram is taken from a little leaflet which was distributed by the promoters of this road, and which was calculated to bring to the attention of property holders at a glance the advantages of such a highway.

On this particular piece of road, as well as on many others with which the writer is familiar, the daily papers in the territory affected were liberally provided with articles describing the proposed construction, and the advantage which it would be in the particular territory in which the road was located.

Especial care, however, has to be taken in preparing newspaper matter, to write it in such a way that it will be acceptable to the newspapers. Publicity agents at times defeat their own purposes by sending out too much matter and not writing it with sufficient discrimination. An editor is always attracted by something which seems to have news value; while, on the other hand, he is deluged almost every day with matter which has no other purpose than to promote some one's particular scheme. It is necessary, therefore, that such matter should tell something definite, new and local, and not simply be a rehash of the general arguments in favor of good roads, or, more specifically, of concrete roads. These arguments can come in incidentally, but if they are made the main point of the story it will very likely reach the waste basket. If it can be found, for instance, that a certain farmer lost a number of dollars by not being able to get his hogs to market at the time the price was highest, because of the impassable condition of the roads, this will be something which has a certain amount of news value and at the same time will be the strongest kind of an economical argument for good roads.

While on the matter of newspaper publicity, it should also be mentioned that the help of the newspapers should be enlisted after the roads are secured, in publishing full accounts, preferably with illustrations, of the beginning of the road, and later the various features of its construction.

In order to secure the largest amount of publicity

SECTION TWO

The Chicago Daily

THURSDAY, APRIL 16, 191

OV. DUNNE STARTS OOD ROADS' WORK; ROWDS GREET HIM

Gov. Dunne Observes Good Roads Day in Practical Manner.

How a Newspaper Featured the Beginning of a Road possible, it is well to have public exercises kind when the first work on the road is do will get a large number of people together also get a considerable amount of publicity : papers in the locality, remembering always more prominent the men secured for addresse time, the larger will be the attendance and th will be the publicity given by the newspapers.

Booster meetings must also be consid any promotional work for concrete roads. Mar payer, if met face to face on his own premi draw within his shell and become proof aga kind of argument; but if one can succeed in him out to a meeting where enthusiasm ru and his neighbors are voicing their approval plan, this same man will many times give a less reluctant consent. These meetings can wherever a sufficient number of people can be together for them; in country school houses, at fairs, at picnics, even from an automobile on th corners. In some localities it has been found p to form at these meetings regular local associat the promotion of the work, and in some cases a general association throughout the entire t to be affected by the proposed improvement. stance, in the territory in Wisconsin shown on companying map, there is an association kn the Fox River Valley Highway Association. M ships in this association are sold at $1.00, this the organization a fund to help carry on the worl at the same time each member is provided with ter button, this also helping to spread the pu If it is possible to hold booster meetings un auspices of civic clubs, commercial associations, advertising clubs, or some other well-known and influential association, it will be all the better. Some of the most forcible and influential speakers should also be secured to give addresses before meetings of county boards in the territory affected.

The help of the cement companies who are selling cement in the territory can also usually be secured in any pomotional work which is being carried on.

CHAPTER XX.

Bridges and Culverts.

This is a subject which is worthy of an entire separate treatise and which can necessarily be treated only in outline in a single chapter here. It is one which is so closely related to highway betterment, however, that this volume should at least call attention to the great advantages of concrete for this class of structures.

If a roadway is to be of a permanent material, one which largely eliminates the items of repairs and rebuilding, the bridges and culverts should also be of such a material, else much of the advantage will be lost. A smooth, durable roadway will be of little value in a spring freshet if the bridges crossing it have been carried away; nor will it be of much advantage to the farmer hauling a heavy load to market if some culvert of primitive type has collapsed.

With the rapid increase in the amount and weight of traffic, an increasing amount of attention is being given to this subject.

In repairs alone, entirely outside of new construction, a great amount of money is spent wastefully. When it is considered that the major portion of the money might have been saved had a more enduring form of structure been adopted in the first instance, it becomes apparent that true economy lies in that class of construction which is permanent, and that the short-sighted policy which adopts a cheap form merely because it is cheap results really in a waste of money.

In view of the foregoing statement, it seems that it should be clear to every official who has anything to do with the construction of culverts or bridges, that he should bear constantly in mind the fact that permanent structures are the cheapest, and cause the culverts of his town to be built in a manner to forever eliminate the repair expense, which at the present time forms such a large item of cost.

There are several kinds of material for the construction of such bridges, such as:

1. The wooden bridge, with pile bents.
2. Steel frame, or superstructure, on piling.
3. Steel superstructure on masonry abutments, with wood floor.
4. Steel superstructure on abutments, with a concrete floor.
5. Large sewer-pipe or tile.
6. Culverts of smooth or corrugated steel pipe, galvanized or painted.
7. Bridges and culverts of reinforced concrete, of any span or shape.*

A bridge or culvert on any highway must necessarily be such as to require little attention or care. It is safe to say that we hardly have a bridge on any of our highways that is regularly inspected from time to time. Not until a plank in the floor is broken, or a washout carries away the filling from the approaches of the bridge, or by some condition it is made a dangerous crossing, is it inspected or looked after. In other words, it is necessary to build bridges or culverts that require little care and maintenance.

*This classification, and the discussion of some of the types, follows very largely a paper given by Mr. James A. Mortland before the Nebraska Cement Users' Association.

Wooden bridges surely do not meet this : ment. They require constant attention, and ev are often a menace to safety. In many places, t are carried to a much greater span than would ot be necessary, owing to the fact that it is impra to fill in the approaches. One case is cited w concrete arch of 35-foot span replaced an wooden bridge, and another where a 40-foot c structure replaced one of wood of 66-foot span.

To make culverts of wood, where any amo earth is to be placed on top, is temporizing and end will cost more to replace.

Bridges with a steel superstructure on pilin wooden floors, are not much better than the w bridges and are of no more use in making our hig permanent than an all-wooden structure. Steel b with concrete or masonry abutments and wood are not at all so desirable, as the floors rapidly out, the life of a plank floor on a bridge with orc travel is not more than five years, with many new p needed from time to time in that interval. Steel b on concrete abutments, with concrete floors, are satisfactory, but are likewise expensive; in fact, possible to construct a concrete bridge as cheap ninety-nine cases in a hundred, and the concrete b has the advantage of not requiring painting, and fers no depreciation from the elements.

So far we have considered bridges for l streams or for locations where it would not be poli narrow the waterway to any great extent. But in r localities one bridge in five spans a living stream other four spanning gullies and dugouts that dry for a greater part of the year. Thus we ha

Highway Bridge—Luten Design

condition presenting itself to the highways as it the railroads; and we find the railroads have alm variably constructed such a waterway by means verts under their tracks, so as to carry a norma fall, and filling on top, giving them a continuous bed; with a flood, the water may be held back time, but soon can get away without any great d from backing up. It is possible to adopt this met placing culverts in such places on the highways, a filling on top a roadway is obtained that is perm and with no danger of ever giving out. By red the length of the bridge and placing a culvert the ant cost of a permanent culvert is oftentimes less the amount it would take to build a wooden l necessary to span the ditch.

Here are two instances of reducing the water or rather of filling up an open ditch: First, where wooden bridges had been built in thirty-five year last one was 44 feet long, and it had served its tin it was removed and a concrete culvert was built inside dimensions of 4x5 feet; and this culver proved ample for all the water that can flow in the Another bridge 56 feet long which has grown fr span of 16 feet in ten years, was rendered unsafe b bank slipping in, breaking off the piling. This w placed with a concrete culvert five feet square and teen feet of dirt placed on top, making a perm roadway instead of having a plank floor over a gulley. These two cases show that often there is a p roadway where it would be possible to have a dirt Then such gullies or washouts are usually at the fo a hill or between hills, and the cutting down of the and filling in of the culvert improves the whole road and makes a permanent improvement.

Having these conditions, it is well to consider the various materials available for constructing such culverts as needed.

Large sewer-pipe has been used with varying degrees of success. Much depends on the placing of the pipe and the character of foundation on which they rest, and in the cementing of the joints. The disadvantage is in the frequent unequal settling of the pipe when the earth is filled in, and this causes a break in the flow of the water and it will tend to fill up the pipe, likewise increasing the chances of undermining the pipe. To make a concrete footing for the pipe and to carry this up the sides to the horizontal diameter adds greatly to the cost, while it improves the value of the pipe as a culvert.

End walls over the top of the pipe are needed to prevent the fill from washing down into the opening; also wing walls are necessary to hold the dirt on the sides. The attaching of these walls to the pipe is a difficult matter and is usually very unsatisfactory, owing to the fact of not being able to get a good bond between the pipe and the concrete or mortar of the walls.

There have been many types of circular steel culverts brought into the market in the past few years having some merit, but the fault is rusting. The same objection of attaching wing and end walls to this type of culvert as with sewer pipe is true. For any given area of carrying capacity it is possible to construct concrete culverts as cheaply as the steel pipe, and provide the concrete culvert with wing and end walls.

Concrete Slabs, T-Beams, and Reinforced Con-

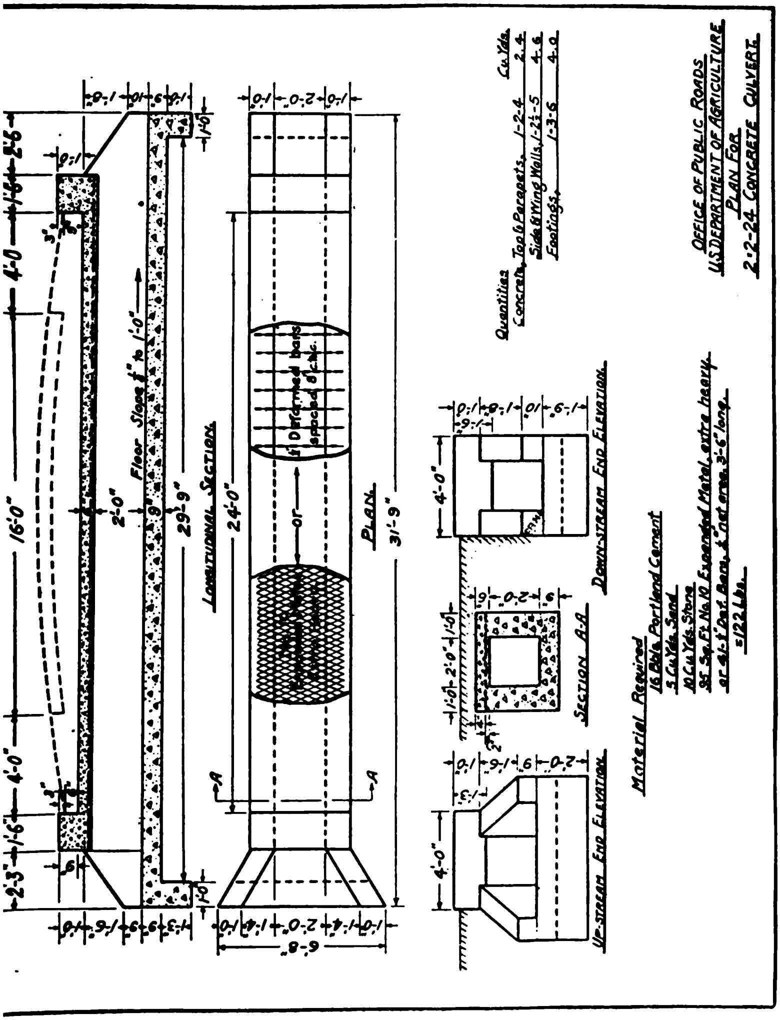
crete. The simplest form of concrete construction for bridges or culverts is the concrete floor or slab, corresponding to the wooden plank floor. The concrete slab may be used for greater spans than the plank floor, and it may also be strengthened for greater spans by constructing concrete beams beneath the floor to support it. This is then known as the "T-beam" type of construction, from its resemblance in form to the capital letter T.*

These types of concrete construction may be strengthened further by placing steel rods, expanded metal, or woven-wire cloth near the bottom of the slab, and steel rods near the bottoms of the beams. The advantages of using the steel reinforcement are that it has a greater tensile strength than concrete and that its location in the lower part of the concrete slab or beam brings it into tension when the beam is loaded. Moreover, the compressive strength of concrete is greater than its tensile strength, and therefore the steel strengthens that part of the concrete structure which is subject to tensile stresses and is most liable to fail first.

This method is therefore more economical and makes it possible to bridge greater spans, within practical limits of cost, than can be done with plain concrete alone.

Box Culverts. The application of the concrete slab is to be found first in the construction of box culverts. Public highways in this country are crossed by many small open ditches. Many of these ditches are provided with wooden stringers and plank floors, which, however, are so nearly worn out and are in such poor

*In the description of these types the author follows Bulletin No. 43 of the Office of Public Roads.


Office of Public Roads
U.S. Department of Agriculture
Plan For
2-2-24 Concrete Culvert
Quantities
Cu.Yds.
Concrete Top & Parapets 1-2-4 2.4
Side & Wing Walls 1-2½-5 4.6
Footings 1-3-6 4.0
Material Required
16 Bbls. Portland Cement
5 Cu.Yds. Sand
10 Cu.Yds. Stone
56 Sq.Ft. No.10 Expanded Metal extra heavy
or 41-½" Def. Bars, ½" net area, 3'-6" long.
=122 Lbs.
Longitudinal Section
Floor Slope ⅛" to 1'-0"
Plan
½" Deformed bars spaced 8" c.to c.
or
Section A-A
Up-stream End Elevation
Down-stream End Elevation

condition that they do little more than invite accident. There is continual annoyance and expense in keeping these in repair, and this may all be avoided by building small concrete box culverts at these places.

The box culvert gets its name from its similarity to a box with open ends. It has a floor, which may be of plain concrete or may be paved with stone. The two sides and wing walls at the two ends may be of plain concrete or reinforced with steel, but the cover and parapets should always be of reinforced concrete.

The sketch shown on page 166 is made from a working plan prepared in the Office of Public Roads for a concrete box culvert, which has an opening 2 feet wide by 2 feet high.

This type of construction is practical under the majority of conditions for spans up to about 8 feet, which, as a matter of fact, forms a large percentage of all the culverts needed. Conditions may occur where it will be practicable to apply the box type, with some modifications, to greater spans than those mentioned, such as where the foundation is soft or liable to much erosion from swift currents. The floor may then be reinforced with steel, so that it will have greater strength to act as a beam to distribute the load over a greater area. It may also be extended back of the side walls to act as a footing. With suitable "cut-off" walls to prevent current of water from running beneath this floor, the foundation will be well protected from erosion. Under such conditions this modified type, with further modifications in the cover, may be practical for spans up to 20 or 30 feet.

Reinforced Concrete Slab Culverts. The length of he spans over which reinforced concrete slabs may be built within the limits of practicability and safety depends much upon the loads to be carried. The depth and amount of fill over the culvert, which may distribute the effect of the concentrated load, is also an important factor.

On main roads, where concentrated loads, such as road rollers or traction engines, are to be provided for and the depth of fill over the culvert is sufficient only to provide a cushion of earth from 1 to 2 feet in depth, the concrete slab is practical for spans up to about 10 or 12 feet, while for greater spans than this, under these conditions, other types better adapted to the longer spans should be used.

Under conditions of less severe loading the spans for the slab may be increased up to 16 or possibly 20 feet, but it does not seem advisable to use them for these greater spans in view of the possibilities of a nominal future growth of traffic requirements.

Reinforced Concrete T-Beam Culverts. The reinforced concrete T-beam type of construction supplements the slab type and begins to be practical in point of economy at the point where the slab ceases to be economical—that is, for spans from about 10 to 12 feet and more—under the conditions of concentrated loads, such as road rollers or traction engines. This type of construction has been designed for spans up to 50 feet long, but whether or not it is practical for spans as great as that may depend upon several conditions, which must be carefully determined in each individual case.

Concretė-Steel I-Beam Culverts. One of the best types of culverts for spans from 10 to 30 feet long is the steel I-beam incased in concrete, upon which rests a relatively thin concrete slab which forms the cover for the culvert. The slab is designed to carry the load for a span equal to the distance from center to center of the steel I-beams, while the beams are designed to carry the load over the clear span from one side wall or abutment to the other.

Among the best features of this type of construction are its safety and ability to withstand severe and unfavorable conditions, such as the unequal settlement of abutments, which may cause cracks in the concrete that would cause other types to fail. In this type, however, the load is carried principally by the steel I-beams, whose strength is not destroyed by the settlement of the abutments.

Many structures of this type have been built without incasing the I-beams in concrete, but by merely painting the beams instead, to protect them from rust. The painting, however, must be repeated every few years, at some considerable expense. There is, of course, a great possibility that this painting may never be done, and the better way is decidedly to incase the beams in concrete during the construction, and thus protect them permanently.

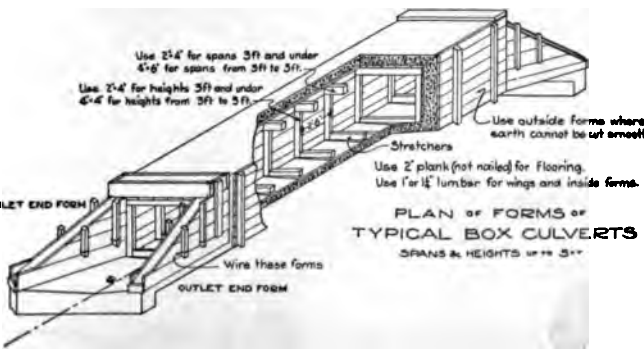
This type also admits of arch construction between the beams for the floor system. By this means space may be saved in the depth of the floor system that may be of value in locations where the area of the waterway or the "head room" is a controlling factor.

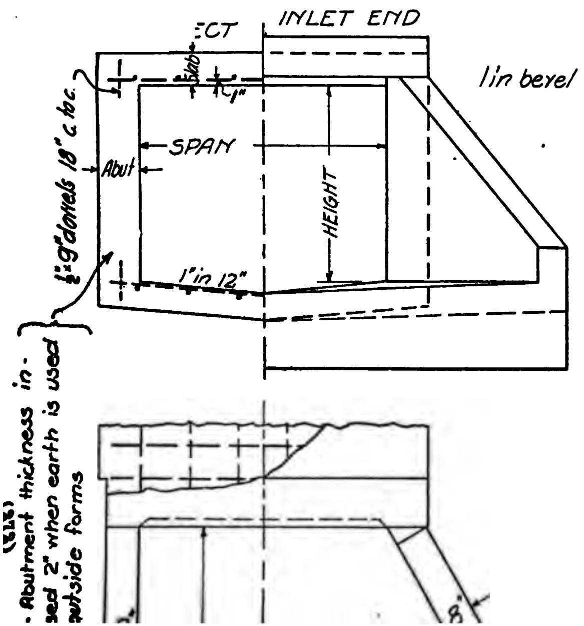
Reinforced Concrete Arches. The reinforced concrete arch has an advantage over the plain concrete arch in the fact that the curve of the reinforced structure may be made more nearly flat than the plain concrete arch, and thereby save in the total height of the structure. This permits it to be used where it otherwise could not be. Under favorable conditions there may be an additional advantage in point of economy, although this can not be stated generally as true in all cases.

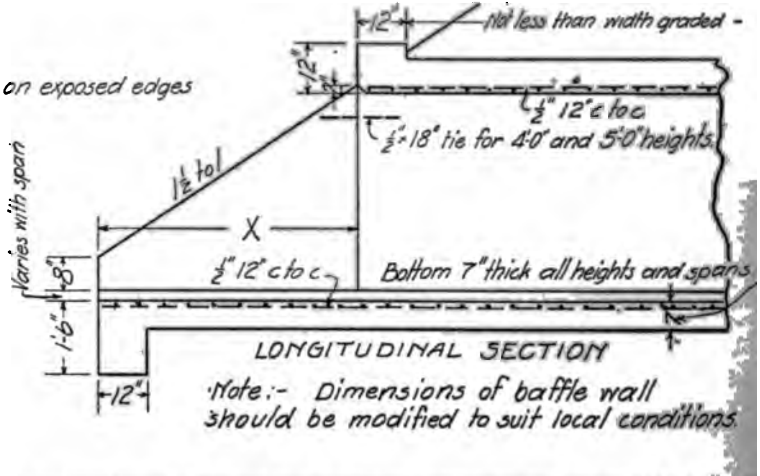
The steel reinforcement in the arch serves the same purpose as in the concrete slab—that is, to increase the strength of the arch rib where the concrete has excessive tensile stresses. In some cases, however, the concrete is also reinforced against compression. It is also possible, when steel reinforcement is used, to reduce the quantity of concrete in the arch rib from the amount that would be required for a plain concrete arch. The reinforced-arch type of construction may be used for practically the same spans as stated for the plain concrete arches.

Cost of Box Culvert. The cost data below is for a small 4x5 box culvert, 26 feet long, built according to the designs here shown, which are taken from a bulletin issued by the North Carolina Geological and Economic Survey.

The work was done by a regular county concrete gang, composed of a foreman, seven men and two teams with drivers, and was completed in four days of 10 hours each. The excavation was light, but the soil was







HEIGHT	SPAN	THICKNESS ABUTMENT	THICKNESS SLAB	LENGTH WING (X)	1/2 WIDTH WING END (Y)	BOX SECTION						INLET END		OUTLET END	
						STEEL									
						TOP	BOTM	DOWELS	WEIGHT LIN. FT.	CONCRETE LIN. FT.		CONCRETE	STEEL	CONCRETE	STEEL
Ft	Ft	Ins	Ins	Ft Ins	Ft Ins	Size	Size	Size	Lbs	Cu yds		Cu yds	Lbs	Cu yds	Lbs.

of a hard, black nature that was hard trimming. Water for mixing had to be hauled two miles.

Sand gravel was used for aggregate in the concrete. The gravel contained a slight excess of sand and worked up in the proportions given. Mixing was done by hand with negro labor. Twisted square steel bars were used for reinforcing.

Labor.

Foreman, 40 hours @ 25c	$10.00	
Culvert excavation, 9 cubic yards @ 80c	7.20	
Labor on forms	14.00	
Mixing and placing, 120 hours @ 15c	18.00	
Hauling water, 20 hours @ 30c	6.00	
Cutting and placing steel, 10 hours @ 15c	1.50	
Cleaning up and removing forms, 10 hours @ 15c.	1.50	
	$58.20	
50% salvage on forms	7.00	
	$51.20	
Moving on and off job	10.00	
Total labor at culvert		$61.20

Material (Laid Down at Culvert).

Cement, 26 barrels @ $1.80		$46.80
Hauling cement, 12½ hours @ 30c	3.75	
Gravel, 18½ cubic yards @ $1.10 f. o. b. cars Ennis, Texas	20.35	
Hauling, 18½ cubic yards, 46 hours @ 30c (75c per cubic yard)	13.80	
Steel, 1,072 pounds @ 2½c	26.80	
Hauling steel, 2 hours @ 30c		.60
Lumber, 1,000 feet B. M. @ $25.00		25.00
Hauling lumber, 3 hours @ 30c	.90	
	$138.00	
75% salvage on form lumber	18.75	
Total cost of material at job		119.25
Total cost of job		$180.45
Cost per cubic yard of concrete in place, exclusive of culvert excavation		9.37
Cost per cubic yard of concrete in place, exclusive of excavation and steel		7.85

The quantities were as follows: 14½ cubic yards of 1:3:5 concrete; 4 cubic yards of 1:2½:4 concrete; 432 pounds of ¾-inch steel; 640 pounds of ½-inch steel, and 1,000 feet B. M. of lumber.

Luten Truss. There have been built many small bridges and culverts using a built-up reinforcement known as the Luten truss. It is intended for slab bridges of spans up to 20 feet and for girder bridges of greater length. The steel is in the form of a rigidly constructed unit clamped together with locked wedges. It is set directly on the forms and the concrete poured around it.

Size of Culverts. A number of formulas, designed to aid in estimating the size of culverts, and based on the considerations stated, have been proposed. The most common of these is Myer's formula, which states the relation between the drainage area as follows:

The required area of waterway in square feet is equal to the square root of the drainage area in acres, multiplied by a number varying from 1 to 4, depending on the character of the watershed. For slightly rolling ground, this number is taken as 1; for moderately hilly ground, at 1½ or 2; and for steep, rocky ground, at 4.

For a drainage area of 40 acres, this would mean that level or slightly rolling ground would require about 6 square feet, which is a 2x3-foot box, or a 36-inch pipe; if moderately hilly, it would require about 12 square feet of opening, which is a 3x4-foot box or a 48-inch pipe; or, if the ground is very steep and rocky, from 25 to 30 square feet, meaning that a 5x6-foot culvert or a 6-foot pipe will be required.

There are other similar formulas, but all are valuable simply as guides to the judgment in forming an

Concrete-Steel Marsh Rainbow Arch Bridge Over Little Cottonwood River,
Blue Earth County, Minn.

inion as to the reliability of any information gathered om local sources. It can readily be seen that the selecon of the constant multiplier is left entirely to one's judgment, and this makes the result obtained by the use of the formula almost wholly a matter of opinion.

A very important thing to be taken into account is the height of the fill over a culvert. If a culvert discharges under a head, the discharge is increased very rapidly as the head increases; so that if the fill is deep, and the water can be dammed to some extent, it is safe to use a smaller culvert than would be safe with a shallow fill.

The shape of the opening in a culvert is of little significance, provided that the area of the opening is sufficient. For the larger sizes, it certainly is easier to build the culvert rectangular in form, with a flat top, principally because of the fact that the forms can be built more easily, and with less cutting of lumber. There is added advantage in that for any given span a rectangular opening will give more waterway than an arched opening. Also the width of the opening remains constant, regardless of the height to which the water may rise.

It is usually an advantage in the larger culverts to have a separate foundation for each side wall, but in the smaller culverts the whole bottom should be paved, as in this way the foundation is protected from scouring. Especial care should be taken to have the culvert discharge in such a way that the lower end will not be undermined.

The forming of small culverts is a matter of some difficulty; though not so much the forming itself as the removal of the form after the culvert is set. Mr. M. W. Torkelson, bridge engineer for the Wisconsin Highway Commission, states that he has seen numerous small culverts with a portion of the form lumber remaining fast in the culvert. This is a serious condition, because it is apt to cause the culvert to become filled with trash, effectually stopping the flow of water through the culvert and rendering it liable to a washout. He believes that much of this trouble could be obviated by building the forms less tight, and covering open spaces in the forms with building paper fastened to the forms with small tacks. It is also thought that the boards composing the forms could be leveled in such a way as to make their removal easier. Also, no culvert should ever be less than 18 inches square if there is room to permit.

In the building of these smaller culverts, the cost of forming is one of the most important items. The amount of concrete required is very small. The labor of excavation, etc., is also usually slight, but the trouble of forming and of removing forms is considerable. The writer believes that these small culverts can best be built with some permanent forms which can be easily set up and conveniently removed as soon as the concrete has set reasonably well, and then used at another point. It seems certain that such a form can best be built of metal, especially for a culvert with a circular opening. There are several such forms on the market.

Mr. Torkelson, quoted above, says that it is the practice of the Wisconsin Highway Commission to use concrete wherever possible. It believes that where materials are reasonable in price, and the cost of foundation work not too great, that concrete is the most economical material. It recommends the following general rule for design: For the shorter spans up to about 25 feet, flat slab construction is recommended; for spans from 25 to 40 feet, the through girder or arch type; and for greater spans, arches.

CHAPTER XXI.

SIDEWALKS, CURBS AND GUTTERS.

This is a subject closely allied to the gen(treated in this volume, and yet one on which say little more than to call attention to the specifications of the American Concrete : printed in Appendix K and Appendix L.

Concrete has come to be the standard mat these purposes, and its utility is never questio1 very few cities indeed is anything else now 1 the construction of sidewalks, curbs and gutter few smaller places the plank sidewalk is still but even in these towns most of the residents bu concrete of their own accord, and the city cour rapidly seeing the wisdom of this course and by one making the concrete sidewalk mandatory

In isolated cases, too, stone curbing is us(they are so infrequent as merely to emphasize t eral use of concrete for this purpose.

Concrete for these purposes has everythin favor. It is long lived, pleasant to the tread, s and what is perhaps more important from the point of city economy, it does not become dila causing accidents and involving the city in cc damage suits, as is the history of the plank walk ing all these things into consideration, concret far the cheaper material in the end.

A number of years ago many people hesit put down concrete walks because of the fear th would not get good workmanship. This is no longer true. The method for the laying of such walks has become standardized, as embodied in the specifications given in the Appendix, or in the specifications of progressive cities; and knowledge in regard to concrete has become more widely disseminated, so that almost any reputable contractor can be relied upon to do intelligent and satisfactory work.

It is also true that improvements in methods, the gradual reduction in the price of cement, and the increase in competition in this line of work, have brought the price down considerably; and with lumber constantly rising in price, a concrete walk no longer looks like an extravagance to the ordinary property holder as compared with plank.

The perfection of metal forms for sidewalk, curb and gutter work is perhaps one of the most important developments in this branch of the industry within recent years, and is calculated to add still further to standardization and economy.

Sidewalks, like pavements, may be built in either one or two courses, the latter method being the one in most general use. It is probable, however, that the one-course walk is destined to grow in favor.

APPENDIX A.

SPECIFICATIONS OF AMERICAN CONCRETE INSTITUTE.*

ONE-COURSE CONCRETE STREET PAVEMENT.

Grading.

1. Defined.—The term "grading" shall include all cuts, fills, approaches and all earth moving for whatever purpose where such work is an essential part of or necessary to the prosecution of the contract. When to bring the surface to grade, a fill of one (1) foot or less is required, the area shall be thoroughly grubbed. All soft, spongy or yielding spots and all vegetable or other objectionable matter shall be removed and the space refilled with suitable material.

2. Engineer's Stakes.—Stakes will be set by the engineer for the center line side of slopes, finished grade and other necessary points.

3. Excess Material.—Excess material shall be disposed of as directed by the engineer, the free haul not to exceed .... feet.

4. Over-haul.—Materials hauled a greater distance than the free haul from the place of excavation shall be paid for at the rate of .... cents per cubic yard for each aditional .... feet.

5. Fills.—Embankments shall be formed of earth or other approved materials and shall be constructed in successive layers, the first of which shall extend entirely across from the toe of the slope on one side to the toe of the slope on the other side, and successive layers shall extend entirely across the embankments from slope to slope. Each layer, which shall not exceed one foot in depth, shall be thoroughly rolled with a roller weighing not less than five (5) tons nor more than ten (10) tons before the succeeding layer is placed. The roller shall pass over the entire area of the fill at least twice.

The sides of the embankment shall be kept lower than the center during all stages of the work and the surface maintained in condition for adequate drainage. The use of muck, quicksand, soft clay or spongy material which will not consolidate under the roller is prohibited.

When the material excavated from the cuts is not sufficient to make the fills shown on the plans the contractor shall furnish the necessary extra material to bring the fills to the proper width and grade. When the earth work is completed, the cross section of the road shall conform to the cross sectional drawings and profile attached hereto.

*At the time of the compilation of this book these specifications had not been adopted by letter ballot of the Institute.

6. Slopes.—All slopes must be properly dressed given by the engineer.

7. Finished Grade.—When the grade line is ap the final grade stakes will be set, for which sufficie must be given to the engineer.

Note: (In excavating cuts, it is considered when the line of the subgrade is approached, to con remaining material by rolling. The depth of materi the cut to be compressed to the finished grade by rol depend upon the character of the material.)

Drainage.

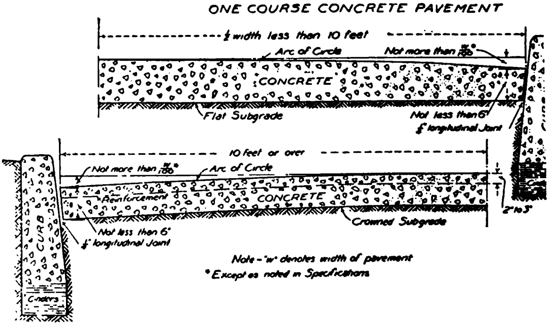
8. Drainage.—The contractor shall construct tile drains as shown in the drawings attached hereto. T laid in the trench at least ....(......) inch and .... (.........) feet deep below th the adjacent curb. Such trench shall be back fill crushed stone or pit run gravel with sand removed after light tamping, shall be .... (........ in depth.

9. Catch Basins.—Catch basins shall be placed structed as per plans.

Sub-Grade.

10. Construction.—The bottom of the excavation top of the fill when completed shall be known as the su

ONE COURSE CONCRETE PAVEMENT



and shall be at all places true to the elevation as sh the plans attached hereto. The street shall be grade curb to curb to the proper sub-grade to permit of sp thickness of paving materials being laid to bring the f surface of the pavement to the lines and grades as on the plans. The sub-grade shall be brought to a fi yielding surface by rolling the entire area with a self-pr roller weighing not less than ten (10) tons, and all p of the surface of the sub-grade which are inaccessible to the roller shall be thoroughly tamped with a hand tamp weighing not less than fifty (50) pounds, the face of which shall not exceed 100 square inches. All soft, spongy or yielding spots and all vegetable or other objectionable matter shall be entirely removed and the space refilled with suitable material.

Where considered necessary or of assistance in producing a compact solid surface the sub-grade, before being rolled, shall be well sprinkled with water.

When the concrete pavement is to be constructed over an old roadbed composed of gravel or macadam, and the concrete is to be wider than the old gravel or macadam road, the latter should be entirely loosened and the material spread for the full width of the roadbed and rolled. All interstices shall be filled with fine material and rolled to make a dense, tight surface of the roadbed.

11. Acceptance.—No concrete shall be deposited upon the sub-grade until it is checked and accepted by the engineer.

12. Completion.—Upon the sub-grade thus formed shall be laid the concrete pavement as shown in the plans attached hereto.

Materials.

13. Cement.—The cement shall meet the requirements of the Standard Specifications of Portland Cement, adopted by the American Society for Testing Materials, August 16, 1909, with all subsequent amendments and additions thereto adopted by said society.

When the cement is not inspected at the place of manufacture it shall be stored a sufficient length of time to permit of inspecting and testing. The engineer shall be notified of the receipt of each shipment of cement.

14. Fine Aggregate.—Fine aggregates shall consist of sand or screenings from clean, hard, durable crushed rock or gravel, consisting of quartzite grains or other hard material graded from fine to coarse with the coarse particles predominating and passing, when dry a screen having ¼-inch openings. It shall be clean, hard, free from dust, loam, vegetable or other deleterious matter. Not more than twenty (20) per cent shall pass a sieve having fifty (50) meshes per linear inch.

Fine aggregates containing more than three (3) per cent of clay or loam shall be washed before using.

Fine aggregate shall be of such quality that the mortar composed of one part Portland cement and three (3) parts fine aggregate by weight when made into briquettes, will show a tensile strength at least equal to the strength of 1 to 3 mortar of the same consistency, made with the same cement and Standard Ottawa sand. In no case shall fine aggregate containing frost or lumps of frozen material be used.

15. Coarse Aggregate.—Coarse aggregate shall con clean, hard, durable crushed rock or gravel, graded l free from dust loam, vegetable or other deleterious and shall contain no soft, flat or elongated particles. size of the coarse aggregate shall be such as to pass and one-half (1½) inch round opening and be retained screen having one-quarter (¼) inch openings. In nc shall coarse aggregate containing frost or lumps of material be used.

16. Natural Mixed Aggregate.—Natural mixed aggr shall not be used as they come from deposits, but sh screened and used as specified.

17. Water.—Water shall be clean, free from oil, alkali or vegetable matter.

18. Reinforcement.—Concrete pavements twenty feet or more in width shall be reinforced with metal f All reinforcement shall be free from excessive rust, paint or coatings of any character which will tend to de the bond. All reinforcement shall develop an ultimate sile strength of not less than 70,000 pounds per square and bend 180° around one diameter and straighten wi fracture.

Forms.

19. Materials.—The forms shall be free from wai sufficient strength to resist springing out of shape and be equal in width to the thickness of the pavement a edges. Wooden forms shall be of not less than two (2) stock and shall be capped with two (2) inch angle iron.

20. Setting.—The forms, when required, shall be staked or otherwise held to the established line and g and the upper edges shall conform to the established of the street.

21. Treatment.—All mortar and dirt shall be rem from the forms that have been previously used.

22. Width, Thickness of Concrete and Crown.—The crete pavement shall be .... feet wide .... (.........) inches in depth at center and .... (... inches in depth at the sides. The finished surface shall form to the arc of a circle, as shown on the plans atta hereto.

Note: The thickness of the concrete at the edges shal be less than six (6) inches. When pavements twenty (20) or less in width are to be built on approximately level gr and a flat sub-grade is to be used, sufficient fall for drainag the sides of the pavement along the curb shall be provide giving the roadbed the same grade as that proposed for gutter. The crown of all pavements shall not be more than one-hundredth (1-100) of the width except when deemed ad ble by the engineer the crown of a pavement built on a cro sub-grade may be increased to one-fiftieth (1-50) of the wid provide sufficient fall for drainage along the sides of the p ment at the curb.

Joints.

23. Width and Location.—Transverse joints shall be not less than one-quarter (¼) inch nor more than three-eighths (⅜) inch in width, and shall be placed across the pavement perpendicular to the center line, not more than thirty-five (35) feet apart. A longitudinal joint, not less than one-quarter (¼) inch shall be constructed between the curb and the pavement. All joints shall extend through the entire thickness of the pavement and shall be perpendicular to its surface.

24. Protection of Joints.—The concrete at transverse joints shall be protected with soft steel plates, which shall be not less than two and one-half (2½) inches in depth, and not less than one-eighth (⅛) or more than one-quarter (¼) inch in thickness. The plates shall be rigidly anchored to the concrete. The type and installation of the metal protection plates shall meet with the approval of the engineer. The surface edges of the metal plates shall conform to the finished surface of the concrete, as shown on the plans attached hereto. All joints over one-quarter (¼) inch high or one-half (½) inch low shall be removed.

25. Joint Filler.—All joints shall be formed by inserting during construction and leaving in place the required thickness of prepared felt or similar material of approved quality, which shall extend through the entire thickness of the pavement.

Measuring, Mixing and Placing.

26. Measuring.—The method of measuring the materials for the concrete, including water, shall be one which will insure separate uniform proportions of each of the materials at all times. A sack of Portland cement (94 pounds net) shall be considered one cubic foot.

27. Mixing.—The materials shall be mixed to the desired consistency in a batch mixer of approved type and mixing shall continue for at least forty-five (45) seconds after all materials are in the drum. The drum shall be completely emptied before mixing successive batches. The drum of the mixer shall revolve at a speed not less than the minimum nor more than the maximum number of revolutions shown in the following table:

Rated Capacity cu. ft. unmixed material	Capacity Bags of cement in 1:2:3 mix	Revolutions per minute of drum	
		Min.	Max.
7 to 11	1	15	21
12 to 17	2	12	20
18 to 23	3	12	20
24 to 29	4	11	17
30 to 33	5	10	15

28. Retempering.—Retempering of mortar or co which has partially hardened, that is, mixing with addi materials or water, shall not be permitted.

29. Proportions.—The concrete shall be mixed i proportions of one (1) sack of Portland cement to not than two (2) cubic feet of fine aggregate and not more three (3) cubic feet of coarse aggregate, and in no case the volume of the fine aggregate be less than one-half the volume of the coarse aggregate.*

A cubic yard of concrete in place between neat shall contain one and seven-tenths (1.7) barrels of ce

The engineer shall compare the calculated amou cement required according to these specifications and attached hereto with the amounts actually used in each tion of concrete, between successive transverse joints, a termined by actual count of the number of sacks of ce used in each section. If the amount of cement used in three adjacent sections (between transverse joints) is by two per cent, or if the amount of cement used in any section is less by five per cent than the amount hereinb required the contractor agrees to remove all such sections to rebuild the same according to these specifications, a expense.†

30. Consistency.—The materials shall be mixed sufficient water to produce a concrete which when depo will settle to a flattened mass, but shall not be so wet a cause a separation of the mortar from the coarse aggre in handling.

31. Reinforcing.—Concrete pavements twenty (20) fe more in width shall be reinforced. The cross-sectional are the reinforcing metal running parallel to the center line of pavement shall amount to at least 0.038 square inch per of pavement width and the cross-sectional area reinfor metal which is perpendicular to the center line of the p ment shall amount to at least 0.049 square inch per foo pavement length.

Reinforcing metal shall not be placed less than two inches from the finished surface of the pavement and ot

*When the voids in the coarse aggregate by careful dete nation are thirty-five (35) per cent or less, the concrete may mixed in the proportion of one (1) sack of Portland cement not more than two (2) cubic feet of fine aggregate and not m than 3½ cubic feet of coarse aggregate. The void determina on every load of material delivered to the work is the only surance of uniformity in this regard.

†A cubic yard of concrete in place between neat lines s contain at least 1.75 barrels of cement when the voids in coarse aggregate exceed forty (40) per cent or are not de mined; at least 1.54 barrels of cement when the voids in coarse aggregate are between thirty-five (35) and forty (40) cent, and at least 1.40 barrels of cement when the voids in coarse aggregate are thirty-five (35) per cent or less.

wise shall be placed as shown on the drawings. The reinforcing metal shall extend to within two (2) inches of all joints, but shall not cross them. Adjacent widths of fabric shall be lapped not less than four (4) inches.

32. Placing.—Immediately prior to placing the concrete the sub-grade shall be brought to an even surface. The surface of the sub-grade shall be thoroughly wet when the concrete is placed.

After mixing the concrete shall be deposited rapidly in successive batches upon the sub-grade, prepared as hereinbefore specified. The concrete shall be deposited to the required depth and for the entire width of the pavement, in a continuous operation, between transverse joints, without the use of intermediate forms or bulkheads.

In case of a breakdown, concrete shall be mixed by hand to complete the section of an intermediate transverse joint placed as hereinbefore specified at the point of stopping work. Any concrete in excess of that needed to complete a section at the stopping of work shall not be used in the work.

33. Finishing.—The surface of the concrete shall be struck off by means of a template or strike board, which shall be moved longitudinally or crosswise of the pavement. The excess of coarse material that accumulates in front of the strike board shall be uniformly distributed over the surface of the pavement. Concrete adjoining the metal protection plates at transverse joints shall be dense in character, and any holes left by removing any device used in installing the metal protection plates shall be immediately filled with concrete.

After being brought to the established grade with the template or strike board the concrete shall be finished from a suitable bridge, no part of which shall come in contact with the concrete. The concrete shall be finished with a wood float in a manner to thoroughly compact it and produce a surface free from depressions or inequalities of any kind. The finished surface of the pavement shall not vary more than one quarter (¼) inch from the true shape.

Protection.

34. Curing and Protection.—Excepting as hereinafter specified, the surface of the pavement shall be sprayed with water as soon as the concrete is sufficiently hardened to prevent pitting, and shall be kept wet until an earth covering is placed. As soon as it can be done without damaging the concrete the surface of the pavement shall be covered with not less than two (2) inches of earth or other material which will afford equally as good protection, which cover shall be

kept moist for at least ten (10) days. When deemed necessary or advisable by the engineer, freshly laid concrete shall be protected by a canvas covering until the earth covering can be placed.

Under the most favorable conditions for hardening the pavement shall be closed to traffic for at least fourteen (14) days, and in cool weather for an additional time, to be determined by the engineer.

The contractor shall erect and maintain suitable barriers to protect the concrete from traffic and any part of the pavement damaged from traffic or other causes, occurring prior to its official acceptance, shall be repaired or replaced by the contractor at his expense, in a manner satisfactory to the engineer. Before the pavement is thrown open to travel the covering shall be removed and disposed of as directed by the engineer.

35. Temperature below 35 Degrees Fahrenheit.—Concrete shall not be mixed or deposited when the temperature is below freezing.

If at any time during the progress of the work the temperature is, or in the opinion of the engineer, will, within twenty-four (24) hours, drop to 35 degrees Fahrenheit, the water and aggregates shall be heated, and precautions taken to protect the work from freezing for at least ten (10) days. In no case shall concrete be deposited upon a frozen subgrade.

Shoulders.

36. Shoulders.—When shoulders are required they shall be built upon the properly prepared sub-grade, as shown on the profile and cross sectional drawings attached hereto. All materials shall meet with the approval of the engineer and the work shall be done to his entire satisfaction.

ONE COURSE CONCRETE HIGHWAY.

The specifications for a one-course concrete highway differ from those for a one-course concrete street pavement only in the following points:

Drainage.

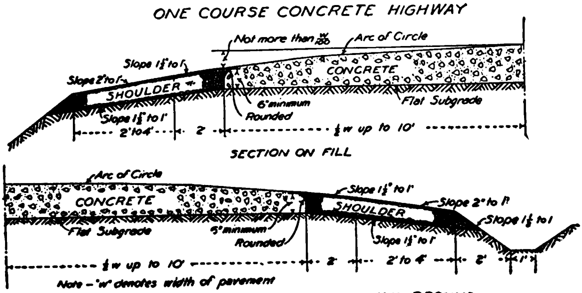
8. Drainage.—The contractor shall construct such drainage ditches as will insure perfect sub and surface drainage during construction and such work shall be completed to the satisfaction of the engineer, prior to the preparation of the road-bed, as herein specified.

Tile drains shall be placed as shown in the drawings attached hereto. Tile to be laid in the trench at least .... (........) inches wide and .... (........)

feet deep below the established grade of the finished pavement, such trench to be back filled with crushed stone or pit run gravel, with sand removed, which, after light tamping, shall be .... (............) inches in depth.

Open ditches must be constructed along the concrete road, as shown on the attached drawing, the dimensions, side slopes and grade of said ditches being as shown on the cross section drawings and profile attached hereto.

ONE COURSE CONCRETE HIGHWAY



SECTION IN CUT ON LEVEL GROUND

At the time of acceptance of the road, ditches must be in perfect condition, with clean slopes and bottom, containing no obstructions to the flow of water.

9. Catch Basins. (Omitted.)

Sub-Grade.

10. Construction.—(Second sentence.)—The roadway shall be graded to the proper sub-grade to permit of the specified thickness of materials being laid to bring the finished surface of the pavement to the lines and grades as shown on the plans.

Forms.

20. Setting.—The forms shall be well staked or otherwise held to the established line and grades, and the upper edges shall conform to the established grade of the road.

22. Width, Thickness of Concrete and Crown.

Note: Crown shall be not more than one one-hundredth (1/100) of the width. The thickness of the concrete at the edges shall not be less than six (6) inches.

Joints.

23. Width and Location.—(Second Sentence.)—When a curb is specified or where pavement abuts a building, a joint

not less than one-quarter (¼) inch shall be placed between it and the pavement.

33. Finishing.—(Following paragraph added.)—The edges of the pavement shall be rounded, as shown on the cross sectional drawings attached hereto.

TWO-COURSE CONCRETE STREET PAVEMENT.

The specifications for a two-course concrete street pavement differ from those for a one-course concrete street pavement only in the following points:

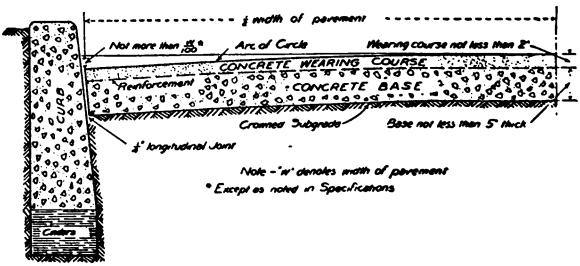
Drainage.

9. Catch Basins.—Catch basins shall be placed and constructed, as per plans, of concrete or of hard burned sewer brick.

Materials.

15A. Aggregate for Wearing Course.—(An additional subhead not found in the specifications for one-course pavement.)

TWO COURSE CONCRETE PAVEMENT
FOR
PAVEMENT OVER 20' WIDE



The aggregate for the wearing course shall consist of two (2) parts of the materials specified under "Fine Aggregate," and three (3) parts of clean, hard, durable crushed rock or gravel, free from dust, soft particles, loam, vegetable or other deleterious matter, and passing when dry a screen having one-half (½) inch openings and be retained on a screen having one-quarter (¼) inch openings. In no case shall aggregate for wearing course containing frost or lumps of frozen material be used.

Forms.

20. Setting.—The forms shall be well staked or otherwise held to the established line and grades and the upper edges shall conform to the established grade of the street.

22. Width, Thickness of Concrete and Crown.—The concrete pavement shall be .... feet wide from face to face of curb. The base of the concrete pavement shall be .... inches in depth at the center and .... inches in depth at the sides. The wearing course shall be of .... (............) inches uniform thickness. The finished surface shall conform to the arc of a circle as shown on the plans attached hereto.

Note: The minimum thickness of the concrete base shall be not less than five (5) inches and the minimum thickness of the wearing course shall be not less than two (2) inches. When pavements twenty (20) feet or less in width are to be built on approximately level ground and a flat sub-grade is to be used, sufficient fall for drainage at the sides of the pavement along the curb shall be provided by giving the roadbed the same grade as that proposed for the gutter. The crown of all pavements shall not be more than one one-hundredth (1/100) of the width, except, when deemed advisable by the engineer, the crown of a pavement built on a crowned sub-grade may be increased to one fiftieth (1/50) of the width to provide sufficient fall for drainage along the sides of the pavement at the curb.

Concrete for Base.

29. Proportions.—The concrete shall be mixed in the proportion of one (1) sack of Portland cement to not more than two and a half (2½) cubic feet of fine aggregate, and not more than four (4) cubic feet of coarse aggregate, and in no case shall the volume of the fine aggregate be less than one-half (½) the volume of the coarse aggregate.

31. Reinforcing.—(Omitted.)

32. Placing.—(Same as for one-course pavement.)

Concrete for Wearing Course.

29. Proportions.—The mortar for the wearing course shall be mixed in the manner hereinbefore specified in the proportion of one (1) sack of Portland cement and not more than two (2) cubic feet of "Aggregate for Wearing Course" hereinbefore specified.

31. Reinforcing.—(Omitted.)

32. Placing.—The wearing course shall be placed immediately after mixing and in no case shall more than forty-five (45) minutes elapse between the time that the concrete for the base has been mixed and the time the wearing course is placed.

33. **Finishing.**—The wearing course shall be struck off by means of a template or strike board, which shall be moved longitudinally or crosswise of the pavement. The excess material which accummulates in front of the strike board shall be uniformly distributed over the surface of the pavement. Concrete adjoining the metal protection plates at transverse joints shall be dense in character and any holes left by removing any device used in installing the metal protection plates shall be immediately filled with a mortar composed of one (1) part Portland cement to not more than two (2) parts of fine aggregate.

(The second paragraph is the same as for the one-course pavement.)

34. **Curing and Protection.**—(The following is added after the first paragraph.)—If at the time the pavement is laid, or during the period of curing, the temperature during the daytime drops below 50° Fahrenheit, sprinkling and covering of the pavement shall be omitted at the discretion of the engineer.

APPENDIX B.

WAYNE COUNTY SPECIFICATIONS.

Parties.

For the sake of brevity, the Board of County Road Commissioners for the County of Wayne will be referred to in these specifications as the Board; the person, firm or corporation to whom the contract shall be awarded will be referred to as the Contractor; and the engineer employed by the Board will be referred to as the Engineer.

Plans and Drawings.

The plan, profile and cross sections on file in the office of the Board show the general locations, profile, details and dimensions. The work will be constructed in all respects according to the above mentioned plans, profile and cross sections, which forms a part of these specifications.

Any variation of location, profile, size and dimensions from that shown on the plans, which may be required by the exigencies of construction, will in all cases be determined by the Engineer; and the Contractor shall not, on any pretense, save that of the written order of the Board, deviate from the intent of these plans and specifications.

On all drawings, figured dimensions are to govern in cases of discrepancies between scale and figures.

Commencement of Work.

The work embraced in these specifications shall be begun not later than ...., and carried on regularly and uninterruptedly, unless the Board shall otherwise direct, and with such force as to insure its completion within the time specified in the contract. The Contractor will give the Board ten days' notice before commencement of the work, and also notice that he has on hand or available the necessary material to uninterruptedly carry on the work to completion.

After the work shall have been commenced, if the same shall be interrupted and delayed by the Contractor from any cause whatever, the Board shall have the right to hire an inspector or watchman and put him in charge of the road during the interruption, and to deduct the wages paid such employe from amount due the Contractor.

Orders to Be Obeyed.

Whenever the Contractor is not present on the work orders will be given to the superintendents or overseers who may be in immediate charge thereof, and shall by them be Board or its duly authorized agents, in anything relating to the work or shall appear to the Board to be incompetent, disorderly or unfaithful, he shall, upon the order of the Board, be at once discharged, and not again employed on any part of the work.

Tiling.

If the work is to be constructed alongside a street railway track, the first work to be done will be the laying of a course of 4-inch land tile on the side of said road next to said track, distant four feet from and parallel with the nearest rail, and at the depth shown on plans. Before the filling back is permitted, the tile must be covered their entire length and one-half their circumference with a layer of tar paper, to keep sand and other material from washing through the joints.

Each proposal must state the price per lineal foot at which the bidder will undertake to do the tiling as above indicated; but the Board reserves the right to reject that part of the proposal relating to tiling, and do that part of the work by day labor, and to accept that part of the proposal relating to roadway proper only, on those parts relating to roadway proper and open ditching; in either of which cases the work of tiling at any given point must be completed before the work on the roadway proper is begun.

Open Ditching.

If the work to be constructed is not alongside a street rail track, an open ditch must be dug along both sides of said road beyond the earth shoulders, location and dimensions of said ditches being shown on plans. This work may be done either before or after the roadway proper; but if done before the ditches must be kept free and clear from rubbish and refuse during the construction of the roadway proper, and left in as good condition in every way as it would have been if done after the concreting and building of shoulders. If the work to be constructed is alongside a street railway track, then an open ditch will be dug only on the side of the work opposite the street railway track.

Each proposal must state the price per lineal foot at which the bidder will undertake to do the open ditching as above indicated; but the Board reserves the right to reject that part of the proposal relating to open ditching and do that part of the work by day labor, and to accept that part of the proposal relating to roadway proper only or those parts relating to roadway proper and tiling.

Grading.

The Contractor shall do all the excavating and filling necessary to bring the subgrade to the required elevation shown on plans and designated by grade stakes. After the subgrade has been prepared, and before any materials are drawn thereon, it shall be rolled with a steam roller weighing at least ten tons. Wherever soft spots occur in the subgrade which cannot be made hard by rolling, the soft material must be removed and material which will pack with rolling must be substituted, and thereafter rolled to the required hardness.

Cement.

The cement to be used has been contracted for by the Board at ..... per barrel, cloth sacks, delivered in carload lots at any railroad siding in Wayne County, on 30 days' time, subject to discount of 1c per barrel if paid within ten days after the car is placed on the siding to which originally ordered. Cloth sacks will be charged at 10c each (included in above price) and when returned to the factory of the company furnishing same, freight prepaid, in good condition, subject to factory count and inspection, will be credited at the same price as charged.

The contractor must order and pay for the cement as per contract referred to, and must take care of and return to the factory all sacks, freight prepaid, in order to be entitled to the credit for same. The contract referred to is on file in the office of the Board, and may be seen upon request.

Sand.

The sand must consist of crushed quartz, trap rock or granite or clean, sharp bank sand, ranging in size from 0 to ¼-inch. It must be washed and screened, and free from loam, clay, mica, vegetable matter and other impurities. The coarser particles must predominate, and the whole be so graded as to reduce the voids to a minimum.

Pebbles.

The pebbles must consist of crushed quartz, trap rock or pebbles, ranging in size from ¼ to 1½-inch.

They must be washed and screened and free from loam, clay, mica, vegetable matter and other impurities, and the whole so graded as to reduce the voids to a minimum.

Concrete.

Concrete shall consist of two parts of cement, three parts of sand, and six parts of pebbles, evenly and thoroughly mixed; parts of cement, sand and pebbles to be determined by measurement.

Mixing.

All concrete shall be mixed in mechanical batch mixers which the Contractor shall furnish, of a type to be approved by the Board; and measurements of all material shall be taken in manner to be approved by the Engineer.

Placing the Concrete in Position.

Before placing the concrete, 2 inch x 6 inch plank be placed on edge and staked in line with the outer e(the pavement, the upper edge of said plank to confo) the finished grade of the road. The workmen shall pla(concrete in position in the pavement where directed.

Finishing the Surface.

The contractor shall employ two men whose special it shall be to follow up the strike-off men and properly the concrete. These men shall work on a bridge restii the form planks and no part of such bridge shall con contact with the concrete.

At night, and at any other time when the work is di tinued for a time, all work must be completed up to a pansion joint, hereinafter provided for. In other word section of the pavement will be allowed to be left unfini for a longer period than 20 minutes if work thereon has started.

In the work of placing the concrete in position, an finishing the subgrade and all other work done under contract, all foot and other traffic, both of employes and o wise, must be kept off the top of the concrete until it thoroughly set; and the Contractor must provide such bri and other devices as will effectually carry out the provis of this paragraph.

Protection of Concrete After Laying.

After the concrete is laid, and until it has thorou set, it shall be protected from the sun by a canvas or o suitable covering.

When the concrete is sufficiently hard to warrant, covering shall be removed and the concrete covered wit layer of sand, loam or other available material about 2 inc in depth, and sprinkled and kept wet 8 days, to prevent surface of the concrete from drying out too rapidly w setting, which covering shall be left on the concrete for additional period of at least seven days, and then be moved and taken away from the road or otherwise dispo of in a manner to be approved by the engineer.

Expansion Joints.

To allow for expansion the pavement shall be built sections 25 feet in length, and at each end of each sectio soft steel plate 3-16 inches thick, extending the entire wi and depth of the road shall be imbedded in the concrete fastened to the section by projections from the steel o) some other manner satisfactory to the Board. It is her expressly stipulated that the joints furnished by the R. D. Baker Company, Home Bank Building, Detroit, will be satisfactory. Between these sections, cutting the entire depth of the concrete, shall be placed an asphalted felt, about ⅛ of an inch thick.

Special care must be exercised to have the expansion plates flush with the surface of the road, so that there will be neither an elevation nor a depression at the joint.

Crossings Over Subgrade.

Before any concrete pavement is constructed, and after the subgrade has been prepared, the Contractor shall provide sufficient planks at his own expense and place and maintain crossings over said subgrade when the same is wet or muddy, unless he shall be excused therefrom, in writing, by the Engineer. Crossings for foot pasengers shall be placed at each cross street to accommodate the public.

Shoulders.

After the pavement is laid, earth shoulders must be built on each side thereof, of sufficient width to bring the total width of the road from berm to berm up to .... feet, as shown on plans. These shoulders must be built in layers not exceeding 4 inches in depth, and each layer must be well packed before the next layer is placed.

When completed, the shoulders must be rolled as directed by the Board, with a roller to be approved by the Board; but such rolling will not be permitted until the concrete has thoroughly hardened, and in any event not until at least 14 days have elapsed after laying the concrete opposite.

Engineer's Stakes.

The work to be done will be staked out by the Engineer, and any stakes broken or removed through carelessness of the Contractor or his employes will be replaced by the Engineer at a cost to the Contractor of one dollar each. The Contractor shall give 24 hours' notice when he needs the services of the Engineer.

Material on Road.

Material delivered on the road in connection with the work must be neatly and compactly piled along the sides in such manner as to cause the least inconvenience to the public and the adjacent property owners. Private drives and road crossings must be kept open as far as practicable, and planked when directed, to the satisfaction of the Engineer. Shade trees and other improvements shall be protected by the Contractor from all damage by stone or otherwise.

Surplus Earth.

All earth not needed for filling or shoulders or otherwise in connection with the work, must be disposed of by the Contractor in manner to be approved by the Engineer, at some point not further distant from point of origin than 1,000 feet.

Obstructing Travel.

Travel upon the road, and upon intersecting roads and alleys, shall not be inconvenienced needlessly; nor shall any portion of the roadway be opened up, nor shall the same be wholly obstructed, except as directed by the Engineer; in which case the Contractor shall cause plain and properly worded signs, "Road Closed, by Order of the Board of County Road Commissioners," announcing such fact, to be placed with proper barricades, and with other signs by day and lanterns by night, plainly indicating the nearest route around the obstructed portion, at the nearest cross road beyond each end of such obstructed portion, and upon intersecting roads, so that travel can pass around same in the shortest and easiest way.

Liabilities of Contractor.

The Contractor must provide a watchman at each end of the road continuously, day and night, and also red lights by night, to effectively keep travel off the pavement, until relieved therefrom by the Engineer, in writing; and the former must assume, and will be held liable for, any and all damage which may arise from his neglect to do so, or from any omissions on his part.

All loss and damage arising from the nature of the work to be done, or from any unforeseen or unusual obstruction or difficulty, which may be encountered in the prosecution of the work undertaken by him, or from the action of the elements, shall be sustained and borne by the Contractor.

Inspection.

The work shall at all times be subject to inspection by the Board and its agents; but such inspection shall not relieve the Contractor from any obligation to perform said work strictly in accordance with these specifications; and the work not so constructed shall be removed and made good by the Contractor whenever so ordered prior to final acceptance, without reference to any previous oversight in inspection.

Defects Before Acceptance.

All depressions, defects and imperfections in any portion of the pavement, whether due to public travel, rain, snow, ice, frost, or other causes, before final acceptance of the work by the Board, shall be repaired and made good by the Contractor at his own expense. All rubbish which may accumulate during and by reason of the work herein provided shall be removed by the Contractor as fast as the pavement is laid, and the streets left clean and in good condition.

Payments.

The Engineer will, on or about the first day of each calendar month during the progress of the work, make and deliver to the Board an estimate, showing, as nearly as he can approximate the same, the number of lineal feet of roadway that have been completed; from which estimate the Board will compute the amount due the Contractor on a pro rata basis; and, after deducting 20 per cent of the whole amount earned, and the sum of all previous payments, will draw its voucher in favor of the Contractor for the balance of the amount found to be due.

When the work is completed and accepted, and final estimate is made, the Board will draw its voucher in payment of the balance due the Contractor; provided, that if, in the judgment of the Board, the proper execution of its work on other roads requires, they may retain an amount equal to the state reward earned on said road until such state reward is paid into the County Road Fund of Wayne County.

Demurrage, Overshipments, Etc.

Inasmuch as all material must be ordered by the Contractor, and unloaded and handled by him, he will be expected to order only so much thereof, respectively, as is required for use on the work, and in such quantities as can be conveniently taken care of by him. Any demurrage or storage charges accruing on any material ordered or shipped, and any additional freight or switching charges accruing by reason of his failure to give proper shipping directions as above required, and charges for any overshipment made, must be assumed and adjusted by the Contractor; and the Board reserves the right to hold back a sum sufficient to cover same until they are properly adjusted. And if it shall appear to the Board after a reasonable time, that the Contractor intends to disregard, or may be unable or unlikely to arrive at a speedy adjustment of any or all of such charges, the Board reserves the right to pay them, and deduct the amount so paid from any amount found due the Contractor.

Proposals.

All proposals must be made upon forms designed by the Board, and must give all the information called for or indicated by such forms; and must be on the basis of the Contractor furnishing all materials, tools, machinery, appliances and labor, except as herein otherwise expressly provided, necessary for the efficient and proper carrying on of the work.

All proposals must be made on the basis of a given price per lineal foot, and must state separately the price for tiling, open ditching, and all other work (which last is designated herein as "roadway proper"). The Board expressly reserves the right to accept the proposal for a greater or less distance than that given in the description of the road above, based upon the amount of money available for use on the road, probable cost of inspection, and other considerations.

All proposals must be sealed; addressed to Wm. F. Butler, Chairman; endorsed, "Proposal to build .... Road"; and accompanied by a certified check on some solvent bank, payable to Wayne County, in the sum of .... Dollars; which check of the successful bidder is to be forfeited as liquidated damages and placed to the credit of the Wayne County Road Fund in case such bidder shall fail to execute a contract to construct the pavement in accordance with these specifications and his proposal, and furnish the bonds herein required, within five days after presentation of draft of same.

Proposals will be received up to 2 p. m., standard time, of .... 191—, and not later, and then publicly opened. The right to accept or reject any or all proposals is expressly reserved.

Engineer's Estimate.

A copy of the Engineer's estimate of the quantities of materials required is attached hereto, marked Exhibit A. The quantities given are the result of calculation, but are to be considered only as approximate. The Contractor is expected to satisfy himself as to the nature, character and quantity of the labor and materials required by a personal examination of the work contemplated.

Assignment of Contract or Moneys.

The Contractor shall not assign nor transfer the contract, nor sublet any portion of the work embraced in it, nor give an order for the payment of any moneys due or to become due by virtue of the contract or of work done under it, without the consent of the Board, in writing, being first obtained.

Work and Forfeits.

If the Contractor shall fail to complete the work within the time specified in the contract, a sum sufficient to pay for inspection and other expenses of the Board, not, however, exceeding in all fifteen dollars per day for each and every day thereafter (Sundays and legal holidays included) shall be deducted from the amount due under the contract, as stipulated damages for failure to complete the work within the time specified therein; provided, however, that all days on which work is suspended by order of the Board or Engineer shall be deducted from overtime, if any there be.

Bills for Extras.

No bills for extras, for labor or material furnished, shall be considered or allowed under any circumstances after the final estimate has been allowed and the pavement duly accepted; nor will any bills for extras, labor or material furnished, be considered or allowed unless said extra work or materials furnished shall have been agreed upon in writing, stating price in detail or aggregate, signed by a majority of the Board and the Contractor, before such extra work is done or materials furnished; and upon completion of such extra work, the Contractor shall immediately file with the Board a statement or bill of items, in duplicate, showing the full amount of his claim for work or materials furnished under the agreement; otherwise he shall be deemed to have waived his claim.

Bonds of Contractor.

The Contractor will be required to execute and furnish, contemporaneously with the execution of the contract, a surety bond in the sum of .... Dollars, conditioned on the faithful performance of the contract, to indemnify and save harmless the Board from all suits and actions of any name or description brought against them on account of any act or omission of the Contractor or his agents.

Any change made in the plans, specifications, agreements or quantities, whether made with or without the consent of the surety company, shall in no way vitiate said bond; the right of the Board to make such changes as it sees fit being expressly reserved.

The Contractor must further agree that so much of the money as may be due him under and by virtue of the contract and work performed thereunder as shall by the Board be deemed prudent, may be retained by them until all suits and claims for damages as aforesaid, shall have been settled, and satisfactory evidence to that effect furnished to the Board.

The Contractor shall also furnish bond in the penal sum of .... Dollars, provided for by sections 10743 and 10744 of the Compiled Laws of 1897, and amendments thereto.

The Contractor must also furnish surety bonds in the sum of .... Dollars, conditions upon the maintenance and proper repair of said road for a period of two years from and after the date of its completion.

APPENDIX C.

MASON CITY SPECIFICATIONS.

1. All streets prior to laying any pavement thereon. shall be graded so that the pavement will be at the established grade when completed. After excavating to sub-grade, unless the engineer deem the natural ground a proper foundation, excavation shall be continued until solid ground is reached, and then re-filled to sub-grade with sand, gravel or broken stone.

2. The contractor shall be required to remove, at his own expense, all obstructions, such as trees, old blocks, debris, etc.

3. All excavated material, gutter stones, planks, macadam, crossing stones, old curbs, surplus earth, etc., shall be the property of the city and be deposited by the contractor in such place and manner as shall be directed by the engineer, the distance not to exceed 3,000 feet. No plowing will be allowed within 3 inches of the bottom of the foundation.

4. When the street shall have been graded and shaped to its proper form, it shall be thoroughly rolled with a ten-ton roller to a thoroughly compact surface. If the ground is wet, sand or gravel is to be put on before rolling.

5. Any depression descovered after this rolling, shall be filled to sub-grade, and this repeated until a road-bed perfect as to grade and form shall have been made.

6. When the use of the roller is impracticable, the foundation must be thoroughly puddled and rammed until compacted to the satisfaction of the engineer.

7. Upon the roadway thus formed, will be laid a foundation of Portland cement concrete five (5) inches thick, to be made as follows: One part by measure of Portland cement; 2 parts by measure of clean, sharp sand, and 5 parts by measure of broken stone.

8. The sand and cement shall be thoroughly mixed into mortar, at the proper consistency, with a batch mixer approved by the engineer. Broken stone, thoroughly cleaned of dirt, drenched with water, but containing no loose water in the heap, shall then be added to the mortar in the proper proportion. The concrete will then be turned and mixed until each fragment is thoroughly coated with mortar.

9. A strictly wet mixture will be required.

10. The concrete thus prepared shall be placed immediately in the work. It shall be spread and thoroughly compacted until free mortar appears on the surface, which shall

be made smooth and parallel to the surface of the finished pavement. The whole operation of mixing and laying each batch of concrete shall be performed in an expeditious and workmanlike manner and be entirely completed before the cement has begun to set.

11. No re-tempering of concrete will be permitted, and concrete in which the mortar has begun to set will be rejected.

12. The thickness of this concrete to be five inches after the same has been compacted.

13. Extreme care should be taken that the sub-grade is kept moist while this concrete is being put in place.

14. No concrete shall be laid when the temperature at any time during the day or night falls below 35° above zero, Fahrenheit.

15. Upon the concrete heretofore specified shall be immediately laid a wearing surface 2 inches in thickness to be made as follows: One part by measure of Portland cement, 2 parts by measure of coarse, clean, sharp sand. The sand and cement shall be thoroughly mixed into mortar of the proper consistency with an approved batch mixer.

16. The mortar thus mixed will be immediately laid upon the concrete heretofore specified.

17. Before this mortar has begun to set, it will be finished off to a smooth surface with a wood float, and before it has completely hardened, it shall be roughened by brushing with a stiff vegetable brush or broom.

18. All forms for expansion and contraction joints shall be made of iron or steel in the form of a template, cut to the desired shape of the street, according to the plans, and of sufficient strength to resist springing out of shape. All mortar and dirt shall be removed from the forms that have been previously used. The forms shall be well staked to the established lines and grades.

19. Contraction joints shall be made entirely through the pavement every 12½ feet at right angles with the street except at expansion joints. The edges of all unprotected expansion joints and all contraction joints shall be rounded to a radius of ½ inch, with proper tools.

20. The sides of all expansion joints that are at right angles with the curb lines, shall be protected by a protection plate to be of soft steel one-quarter (¼) of an inch in thickness, 2½ inches in width, a shear member to be punched from the side of the plate, and bent at right angles to the same. Shear member to be 6 inches long and ¾ of an inch in width, spaced 10 inches center to center. Protection plates shall be in sections not less than ...... feet in length, and cut to the desired crown of the street.

21. The curvature and cross-sections of the paven be made according to the plans governing the same.

22. The cement used in the work will be submit the tests approved and recommended by the Americ ciety of Civil Engineers, which it must stand to the sa tion of the engineer.

23. All Portland cement used in the work shall be City Portland cement, or other Portland cement equa good, which shall be protected from the weather, free exposure to air slacking and from moisture, until used

24. The sand shall be clean, sharp sand.

25. The stone used for the concrete shall be of th quality of hard limestone, or other stone equally as and shall be broken to such a size that the fragments not be larger than will pass through a 1½-inch ring an smaller than a hazel nut. It shall be free from dust, loam or other objectionable material and shall be scr when necessary over a ½-inch screen to eliminate dus small particles.

26. An expansion joint 1 inch in width shall be left to the curb on each side of the street or alley, also a pansion joint ½ inch in width will be left every 37½ across said pavement at right angles to the curbs. Sai pansion joints are to be filled with an asphalt paving of proper quality and consistency approved by the eng It will be applied while heated to a temperature of about Fahrenheit, and shall be so applied that said expansion shall be thoroughly filled clear to the top of surface of pavement.

27. Care shall be taken to obtain a surface fre ridges, at expansion joints, and depressions or unevenne the surface, that will detract from its appearance, or water to lay on the pavement.

28. Any sections having such inferior surface will b jected, and shall be rebuilt by contractor at his own exp

29. Care shall be taken to make the expansion join such a manner that they are practically the same w throughout their depth.

30. Extreme care must be exercised in removing plates or divisions used to make expansion joints; the bı ing out of any portion of the pavement, in removing templates and forms, will not be tolerated, and such aged portions of the work shall be torn out and replace good condition by the contractor at his own expense.

31. The contractor shall keep pavement sprinkled stantly and kept wet once a day for one week after it is or longer if deemed necessary by the engineer.

32. The contractor shall keep the street closed to tr at least two weeks after the completion of same.

APPENDIX D.

THE SPECIFICATIONS OF THE ILLINOIS HIGHWAY COMMISSION FOR CONCRETE ROAD CONSTRUCTION.

Concrete Materials.

Cement.—Some standard brand of Portland cement shall be used which has been in practical use on public works and shall have proved satisfactory therein. No brand of cement shall be used which the engineer deems unfit for the work, nor shall any cement be used which fails to give satisfactory results according to the standard methods of testing as provided by the American Society for Testing Materials. The contractor shall provide sufficient means to protect the cement against dampness, and no cement shall be used which has become caked.

The contractor shall notify the engineer in writing what brand or brands he intends to use, and before ordering the cement shall receive the written approval of the engineer as to the brand selected. It is understood that such approval merely covers the selection of the brand; that the cement itself may be rejected if it fails to meet the requirements herein specified.

Coarse Aggregate.—The coarse aggregate shall consist of clean, hard, sound flint or other hard siliceous pebbles, having a reasonably uniform gradation from a size which will pass through a 1-inch screen to a size that is retained on a ⅛-inch screen, and no gravel composed in part of slate, shale, disintegrated limestone, or other equally soft stone, can be used. Crushed granite or trap rock, graded to the size provided above, may be used. Crushed limestone, graded to the size specified above, may be used only upon the approval of the engineer.

Fine Aggregate.—The fine aggregate shall consist of clean, sharp quartz grains, and shall not contain over 2 per cent of clay or loam. The fine aggregate shall be reasonably uniformly graded from a size which will pass through a ⅛-inch screen down. Sand containing disintegrated shale, slate or limestone shall not be used.

Grading of Aggregate.

The specification that the coarse and fine aggregates must be reasonably well graded shall be interpreted to mean that the percentages of the aggregates passing screens of

various sizes shall be within the limits given in the 1
ing tables:

Table of Gradation of Coarse Aggregate.

Size of screen.	Allowable limits (Percentage passing th:
1-inch square mesh......	100
¼-inch square mesh......	Not less than 45 nor more tł

Table of Gradation of Fine Aggregate.

Size of screen.	Allowable limits (Percentage passing thi
⅛-inch square mesh......	100
$\frac{1}{16}$-inch square mesh......	Not less than 65 nor more th

If the contractor desires to use aggregate which i graded in accordance with the table, he must submit a ple of 50 pounds of such material to the Illinois Hig Commission, Springfield, Ill., one week prior to the da letting of this contract. His sample of aggregate w: analyzed and, if found suitable, its use will be approv writing and the amount of cement that must be used such aggregate will be stated. The aggregate used i construction work must then be graded in accordance the sample submitted, and must be of the same kinc quality as the sample, and the amount of cement used be the quantity required by the engineer in accordance this paragraph instead of the amount provided in para 32. [Proportions for concrete.]

Use of Gravel.

The use of gravel made up of a mixture of the coars fine aggregates described above will not be permitted. I contractor wishes to use such material, he must screen the sizes specified above before proportioning the aggr for mixing.

Concrete Mixer.

The concrete mixer used on the work provided for h shall be a batch mixer of a type approved by the engi The concrete shall receive at least four complete turn the drum before being discharged, and if, in the opinic the inspector, a greater amount of mixing is required, number of turns shall be increased until a thoroughly m concrete is secured.

Proportions for Concrete.

The concrete for the work provided for herein shall sist of 1 part of cement, 2 parts of fine aggregate, and parts of coarse aggregate. The aggregate shall be place the mixer in such manner as to insure that a uniform am of each class of aggregate is used in each batch of conc and the method of measuring the aggregate, whether in w barrows or otherwise, shall be approved by the inspector, 1 sack of cement to be considered as 0.95 cubic feet, and all measurements to be by volume.

Water.

The water used in mixing the concrete shall be clean.

Size and Kind of Roller.

Wherever it is provided herein that rolling shall be done on the roadbed or macadam shoulders, a three-wheel self-propelling roller, weighing not less than ten nor more than twelve tons shall be used.

Roadbed.

The roadbed will be considered as that portion of the road upon which the concrete roadway and macadam shoulder are placed. The roadbed shall consist of the natural earth which has been brought to the proper elevation and cross section and rolled until firm and hard. If sandy or other soil is encountered which will not compact readily under the roller, a small amount of clay or loam shall be added so as to secure a firm, hard surface after rolling. The roadbed shall be thoroughly saturated with water immediately before concrete is placed.

Shoulders and Side Roads.

After the completion of the concrete roadway and macadam shoulders, the side roads are to be shaped in accordance with the cross section shown on the plans and shall be rolled, care being taken not to allow the roller on the edge of the concrete roadway. Upon completion, the cross slope of the concrete roadway, macadam shoulders, earth side roads and ditches shall be as shown on the plans.

Thickness of Concrete Roadway.

The concrete roadway shall have, after completion, the thickness shown on the plans. If a greater thickess is laid than that shown on the plans, no extra compensation will be made therefor.

Under Drains.

An under drain 8 inches wide and 6 inches deep shall be constructed under each of the concrete roadway edges, the entire width of the drain being under the pavement. This under drain shall be filled with broken stone or coarse aggregate before the concrete is placed. At the end of each expansion joint or at intervals of not to exceed 50 feet, blind cross drains, not less than 8 inches wide, shall be constructed from the longitudinal drains before mentioned, to the gutter. These cross drains shall be of such a depth as to drain readily from the longitudinal drains to the gutter, and shall be filled with at least 6 inches of crushed stone or coarse aggregate, and then covered with earth, except that such part of the cross drain as lies under the macadam shoulder shall be filled with stone when the shoulder is constructed. The longitudinal and cross drains shall be completed before the concrete roadway is constructed.

Side Forms.

The concrete roadway shall be placed between side forms of 2-inch plank. The side form plank shall be of a width equal to the thickness of the pavement at the edge. The side form planking shall be accurately set to the alignment and grade of the pavement, and shall be held securely in place by adequate stakes and bracing. Intermediate longitudinal form boards will not be permitted between the side forms to support the templet.

Placing Concrete Roadway.

The concrete for the roadway shall be placed between the plank forms before described, the entire thickness of the concrete being placed at one time. After the concrete has been deposited between the forms, it shall be raked and tamped until the mortar flushes to the top, and the concrete shall be placed in such quantity that there will be a slight excess between the forms. The surface of the roadway shall then be shaped to conform to that which is shown on the plans by striking off with a templet cut to the proper shape. This templet shall be drawn along the forms, and shall be held securely against the top of the forms, and shall be moved with a combined longitudinal and crosswise motion which will prevent dragging the larger particles of the aggregate and marring the surface.

Finishing Surface of Concrete Roadway.

After the surface of the concrete roadway has been struck off to the proper cross section, it shall be finished with wood floats. The wood floats shall be used only to flush mortar to the porous places in the surface, and great care must be taken not to rub hollow places in the surface. The wood float finish shall be made as soon after the concrete has been deposited as possible, and in no case shall the finishing be delayed until the concrete has taken a set.

Covering Concrete Roadway.

After the concrete roadway has been finished as above described, the roadway shall be covered with suitable canvas as soon as this can be done without marring the surface. which shall be kept wet, and as soon as the concrete sets sufficiently, the canvas shall be removed and the concrete covered with earth. The earth covering shall be put on at least 1 inch thick and shall be kept constantly wet for two weeks. The roadway shall be kept close to traffic for two weeks, or, if in the opinion of the engineer, the weather conditions make it advisable, the roadway shall be kept closed to traffic a longer period of time.

Expansion Joints.

Expansion joints shall be provided and spaced as shown on the plans. The expansion joints shall be set at an angle of 60 degrees with the center line of the roadway and shall be of the type shown on the plans. The expansion joints shall be constructed in such manner as to insure that the metal plates, creosoted blocks, or other device provided for the joints, shall conform to the cross section provided for the roadway; and great care must be exercised in placing these joints to insure that there will be neither a depression nor a raised place at the joint.

Cleaning Finished Pavement.

When the concrete roadway has been completed for a sufficient length of time to permit a proper setting of the concrete, it shall be cleaned and then opened to traffic.

Beveling Edges.

If the plans shall provide that the edge of the concrete shall be beveled, then the plank forms shall be removed from the edge of the roadway before the concrete takes its final set, and the edge of the pavement shall be cut off by means of a shovel or other suitable tool so as to give the shape shown on the plans.

Macadam Shoulders.

The macadam shoulders when completed shall be of the width and thickness shown on the plans. The stone for the macadam shoulders shall be deposited, spread and rolled at least twice over, and then covered with screenings or gravel, sprinkled and rolled. When completed the macadam shoulder shall be true to shape and shall be ½ inch above the concrete where it joins the concrete roadway.

Trimming Sides of Road.

The slopes on cuts and fills shall be neatly trimmed to the slopes shown on the plans, and all detritus and surplus materials left after completion of the work shall be removed from the road.

APPENDIX E.

SPECIFICATIONS FOR BLOME GRANITOID PAVEI

Preparation of Sub-Grade.

The sub-grade shall conform exactly to the lines a vations shown on the plans or profiles or as furnished contractor by the engineer in charge or under the di of the engineer. The street shall be graded (excava filled as the case may be) to sub-grade, as specified ai vided for in the general specifications, in such a man to provide a solid foundation for the pavement and all contours and other shaping required in the pavemen be formed and provided for in said sub-grade, so th foundation and pavement hereinafter specified shall uniformly the same thickness throughout.

The contractor will bid with the understanding th sub-grade is to be prepared in such a manner as to s the pavement permanently and retain the original g Any spongy material, vegetable matter or any mater suitable as a foundation shall be removed and the spa filled with proper material, tamped or rolled until co This clause shall not be waived on account of openings in the street by any corporation or individual prior laying of the pavement.

Materials.

The cement used for this work to be a standard br Portland cement complying with all the requirements American Society for Testing Materials. All cement delivered on the work in approved packages bearing brand or stamp of the manufacturer, and 94 pounds cement shall be considered as 1 cubic foot. All cem be carefully protected from the weather until used.

The sand shall be free from clay, loam, vegetable and dust. The grains shall vary in size from ⅛-inch to the finest and so graded that the voids, as determi saturation shall not exceed 33 per cent of the volum wind drifted sand to be used.

The stone used in making the concrete shall be best quality of limestone, trap rock or other hard sto of gravel of size so as to measure not more than 2½ i and in the event of stone being used same shall not m under ¼ inch in dimension.

Clean, acceptable, pit-run gravel, from which all o matter and dust has been eliminated, may be used f concrete bed or lower course of the pavement. The sizes of sand grains and stone in pit gravel and the proportions of fine and coarse aggregate shall correspond to specifications for sand and stone, and deficiencies shall be made up by the addition of sand or crushed stone or gravel.

When delivered on the street these materials shall be placed in such a manner as to be kept clean until used.

Mixing and Laying of Concrete, and Formation of the Blome Company Granitoid Blocking.

The concrete bed or foundation and the surfacing hereinafter specified shall be constructed and manipulated in accordance with the Blome Company patents and processes, utilizing materials mixed in the proportions and laid as hereinbefore specified.

Upon the sub-grade and foundation prepared as hereinbefore specified the Granitoid Concrete Pavement shall be laid, consisting of 6½ inches of concrete at the center of street and gradually decreased to 4½ inches at the curbs or outer sides of pavement, and on same shall be placed the Granitoid surface blocking of uniform thickness of 1½ inches.

Whenever there are street car tracks on the street proposed to be paved, the thickness of the concrete bed shall be equal to the average thickness of the concrete above specified uniformly at all points of the areas to be paved.

The concrete shall be composed of 1 part of Portland cement, 3 parts of sand and 4 parts of limestone, trap rock or other hard stone or clean gravel. These materials to comply with the requirements hereinbefore set forth and shall be mixed by an approved mixing machine, suitable for the purpose, approved by the engineer in charge, each batch being turned at least 5 times before being removed from the mixer.

The concrete shall be thoroughly tamped into place and shall be of the thickness specified, after having been compacted and shall be carefully rammed into sections separated by expansion joints, all as per the Blome Company patents, and the said concrete shall follow the slopes of the finished pavement so that the surface blocking is, and shall be, of uniform thickness at all points.

Granitoid Blocking.

After the concrete has been placed and before it has begun to set, there shall be immediately deposited thereon the Granitoid Blocking, which shall be 1½ inches in thickness, to be composed of 2 parts of approved Portland cement and 3 parts of crushed granite, trap rock, gravel, hard stone or other similarly hard material, which shall be screened with the dust removed therefrom, utilizing the following proportions of this material:

Substantially 50 per cent to be what is known as ⅜-inch size, 25 per cent of ¼-inch size, and 25 percent of ⅛-inch size, with all finer particles removed. This material shall be thoroughly mixed with approved cement and after being wetted to the proper consistency and deposited on the concrete, shall be worked into brick shapes of approximately 4½ inches by 9 inches, with rectangular surface similar to paving blocks, all as per special method and utilizing the grooving apparatus as employed under the Blome Company patents.

The pavement shall be sloped in the manner required by the engineer in charge and in event any part or parts of the pavement, when completed, where slopes, contours, etc., have not been carried out in a true manner, then, under these specifications, the contractor will be required to take up such part or parts, and replace same to the proper level, without expense.

Expansion Joints.

The contractor shall provide for and form expansion joints across the pavement at such intervals as may be necessary, and, where advisable, also along the sides at the curbs or gutters, which expansion joints shall extend entirely through the surface blocking and the concrete and shall be filled with a composition especially prepared for the purpose in accordance with the Blome Company patents. These expansion joints shall be constructed in an extremely careful manner, under specific direction of the engineer in charge.

Patents, Trademarks, Etc.

All fees for any patent inventions, materials, articles or arrangement or other apparatus that may be used upon or be in any way connected with the construction, erection or maintenance of the work or any part thereof embraced in the contract or the specifications, shall be included in the prices stipulated in the contract for said work and the contractor must show conclusively that he has a license permitting and giving him the right to use the patented inventions, materials, articles or arrangement or other apparatus necessary for the construction of the pavement under these specifications and the price stipulated in the contract for said work must include such cost and the contractor must protect and hold harmless the city against any and all demands for such fees or claims.

Blome Company trademark plates will be provided showing the dates of pavement patents, etc., together with trademarks, which plates shall be set by the contractor at such locations as may be designated by the Blome Company.

APPENDIX F.

SPECIFICATIONS FOR BLOME GRANOCRETE PAVEMENT

Preparation of Sub-Grade.

The sub-grade shall conform exactly to the lines and elevations shown on the plans or profiles or as furnished to the contractor by the engineer in charge or under the direction of the engineer. The street shall be graded (excavated or filled as the case may be) to sub-grade, as specified and provided for in the general specifications, in such a manner as to provide a solid foundation for the pavement and all slopes, contours and other shaping required in the pavement shall be formed and provided for in said sub-grade, so that the foundation and pavement hereinafter specified shall be of uniformly the same thickness throughout.

The contractor will bid with the understanding that the sub-grade is to be prepared in such a manner as to support the pavement permanently and retain the original grades. Any spongy material, vegetable matter or any material unsuitable as a foundation shall be removed and the spaces refilled with proper material, tamped or rolled until compact. This clause shall not be waived on account of openings made in the street by any corporation or individual prior to the laying of the pavement.

Materials.

The cement used for this work to be a standard brand of Portland cement complying with all the requirements of the American Society for Testing Materials. All cement to be delivered on the work in approved packages bearing name. brand or stamp of the manufacturer, and 94 pounds net of cement shall be considered as 1 cubic foot. All cement to be carefully protected from the weather until used.

The sand shall be free from clay, loam, vegetable matter and dust. The grains shall vary in size from ⅛ inch down to the finest, and so graded that the voids, as determined by saturation shall not exceed 33 per cent of the volume. No wind drifted sand to be used.

The crushed stone or gravel used in making the concrete, shall be of good quality of limestone, trap rock or other hard stone, or of gravel of size so as to measure no more than 2½ inches, and then graded to the sizes hereinafter mentioned.

Clean, acceptable, pit-run gravel, from which all organic matter and dust have been eliminated, may be used for foundation course of the concrete. The sizes of sand gı and stone in pit gravel and the proportions of fine and co aggregate shall correspond to specifications for sand stone, and deficiencies shall be made up by the additio sand or crushed stone or gravel.

When delivered on the street, these materials shal placed in such a manner as to be kept clean until used.

Manner of Construction of Granocrete.

The Granocrete Pavement shall be 7 inches in thick at the center of street or roadways, and decreased gradu to 5 inches in thickness at the curbs or outer sides of pavement after having been made compact.

Upon the sub-grade, prepared as hereinbefore speci shall be deposited concrete composed of 1 part of Portl cement and 8 parts of an aggregate consisting of appr mately 50 per cent of broken stone or gravel with parti below ½ inch eliminated, 15 per cent of ¼-inch stone gravel with the dust removed, and 35 per cent of clean, pedo sand.

This selection of sizes of ingredients is made in or to produce a mass which will have sufficient voids or occupied spaces to receive enough of the material cor tuting the top wearing surface or layer, hereinafter descril to secure a firm union between the two, whereby the surface is effectively anchored to this foundation.

These materials shall be mixed by an approved mix machine suitable for the purpose, approved by the engin in charge, each batch being turned at least 5 times bef being removed from the mixer.

The concrete shall be thoroughly tamped into place ε to be of the thickness above specified after being compact carefully rammed into sections, separated by expansion joi all as per Blome Company patents and the said concrete sh follow the slopes of the finished pavement so that the surf ing is and shall be of uniform thickness at all points.

Surfacing.

After the concrete has been placed, and before it h begun to set, there shall be immediately deposited there the surfacing which shall consist of 1 part of Portland ceme 1 part of coarse, sharp sand, and 1 part of a mass compos of hard broken stone, conglomerate or gravel of sizes here after mentioned.

The composition of the stone or gravel in the surfaci shall be substantially as follows:

Twenty-five per cent of the stone or gravel in the surf ing shall be ¼-inch size; 50 per cent shall be of ⅜-inch si and 25 per cent shall be of ½-inch size, having in all instan the finer particles eliminated.

The surfacing material shall be thoroughly mixed with approved cement and, after having been wetted to the proper consistency, shall be deposited on the concrete and floated in a manner so as to thoroughly compact all of the ingredients.

The surfacing shall be 1 inch in thickness after having been compacted. The top stratum when compacted, enters the voids of the concrete sufficiently to obtain a firm anchorage thereto, and it is to be understood that definite quantities of material hereinbefore mentioned are employed in the surfacing to protect the sand particles or grain from the effects of travel.

The pavement shall be sloped in the manner as required by the engineer in charge, and in the event there should be any part of the pavement, when completed, where slopes, contours, etc., have not been carried out in a true manner, then under these specifications, the contractor will be required to take up such part or parts and replace same to the proper level without expense.

Expansion Joints.

The contractor shall provide for and form expansion joints across the pavement at such intervals as may be necessary, and, where advisable, also along the sides at the curbs or gutters, which expansion joints shall extend entirely through the surfacing and concrete, and shall be filled with a composition especially prepared for the purpose in accordance with the Blome Company patents. These expansion joints shall be constructed in an extremely careful manner, under specific direction of the engineer in charge.

Patents, Trademarks, Etc.

All fees for any patent inventions, materials, articles or arrangement or other apparatus that may be used upon or be in any way connected with the construction, erection or maintenance of the work or any part thereof embraced in the contract or the specifications, shall be included in the prices stipulated in the contract for said work and the contractor must show conclusively that he has a license permitting and giving him the right to use the patented inventions, materials, articles or arrangement or other apparatus necessary for the construction of the pavement under these specifications and the price stipulated in the contract for said work must include such cost and the contractor must protect and hold harmless the city against any and all demands for such fees or claims.

Blome Company trademark plates will be provided showing the dates of pavement patents, etc., together with trademarks, which plates shall be set by the contractor at such locations as may be designated by the Blome Company.

APPENDIX G.

SPECIFICATIONS FOR BITUSTONE PAVEMENT.

Excavation.

Excavation shall be paid for at the price bid per cubic yard. The portion of the roadway to be improved shall be excavated or filled to the necessary depth below the established grade of the finished roadway to provide for the thickness of 5 inches Bitustone pavement. The sub-grade shall be rolled with a steam roller until its surface is solid, and approximately parallel to the proposed surface of the finished roadway. All excavated material shall be disposed of by the contractor.

Bottom Course of Pavement.

The bottom course of the pavement shall be laid 4 inches thick upon the previously rolled sub-grade and shall be composed of a Portland cement concrete mixed in the proportions of 1 part cement, 3 parts sand or crusher screenings, and 6 parts crushed stone or gravel, slag, broken brick, oyster shells or other mineral aggregate suitable for making concrete. The material used in this concrete shall be of a quality usual in such construction.

Bonding Course.

Upon the bottom course of the pavement, and while the same is still in a wet and plastic condition, shall be spread and leveled, either by tamping or rolling with a light roller, 1 inch of the Porous Bonding Course composed of hard, durable aggregate of approximately uniform size, passing screen openings 1 inch in diameter, and remaining on screen openings ½ inch in diameter, mixed with Portland cement in the proportions of 6 parts of the stone and 1 part of Portland cement. This mixture shall not be sufficiently wet to wash the cement to the bottom of the stone, and must be of such consistency as to insure the coating of each individual stone with a thin coating of pure Portland cement, which shall be stiff enough so as not to be displaced in the subsequent manipulation of grading and tamping. The Bonding Course when finished shall produce a surface in which the coated stones are firmly held together at their points of contact. The Bonding Course shall be kept free from dirt and other extraneous matter, and shall be firmly embedded in the concrete bottom course.

Filler.

After the Bonding Course has become dry, there shall be ɔured upon it and into it sufficient Double Bond Asphaltic iller to penetrate into the voids in the bonding course and ·ave a slight excess on the surface, enough excess to fill the ıperficial voids between the projecting stones, and provide continuous coating of the Double Bond Filler on the surface.

Surface Finish.

While the filler is still hot and plastic there shall be :attered over it a thin layer of crusher screenings which ill pass one-fourth (¼) inch screen openings.

APPENDIX H.

DETAIL SPECIFICATIONS FOR DOLARWAY PAVEMEN'

1. All streets, prior to laying the pavement thereon, sha be graded as directed by the engineer. After excavating tl sub-grade, unless the engineer deems the natural ground proper foundation, excavation shall be continued until soli ground is reached and then refilled to sub-grade with san cinders, gravel or broken stone.

2. When the sub-grade shall have been formed and pro; erly shaped, it shall be rolled with a roller weighing not les than ten tons, to a thoroughly compact surface. If the rollin develops wet or soft spots, they must be filled with dr cinders, sand or gravel.

3. Any depression discovered after rolling shall be fille to sub-grade, re-rolled, and this operation repeated until roadbed perfect as to grade and form shall have been made.

4. When the use of a roller is impracticable, the founda tion must be thoroughly puddled and rammed until com pacted to the satisfaction of the engineer.

5. Upon the sub-grade thus formed shall be placed : layer of Portland cement concrete .... inches thick, of th following proportions: ....parts by volume of Portlan cement; ....parts of clean sharp sand and ....part of broken stone or clean gravel.

Within twenty (20) minutes after the concrete is laid i shall be struck off with a template approved by the engineer and as soon thereafter as practicable shall be floated suf ficiently to bring the finer particles to the top so as to pro duce a smooth, uniform surface.

The concrete shall be kept wet, if directed by the engi neer, for a period of seven days.

6. If gravel is used for concrete, it must be free from clay or other injurious material and shall contain no stone over two inches in diameter.

Care must be taken, if the gravel is not screened, that the ratio of the sand to the stone in its composition shall not exceed the above specifications for proportion of materials.

7. If broken stone is used for concrete, it shall be of the best quality of limestone, or other stone equally good, and shall be broken to such size that no fragment shall be larger than will pass through a 2-inch ring, nor smaller than ½ inch in its greatest dimension. It shall be clean and free from all foreign matter and shall be uniformly graded.

8. The cement used in the work will be submitted to the tests approved and recommended by the American Society for Testing Materials, and any cement failing to comply with these requirements shall be rejected. All cement to be used

on the work shall be suitably protected from exposure to moisture until used.

9. The ingredients of the concrete shall be thoroughly mixed in a mixer approved by the engineer; enough water being added to produce a plastic mass that will flush slightly under light tamping, but not so thin that the mortar will separate from the coarse aggregate.

10. No retempering of concrete will be permitted, and that in which mortar has begun to set shall be rejected.

11. No concrete shall be laid when the temperature at any time during the day or night falls below thirty-five (35°) degrees above zero, Fahrenheit.

Longitudinal expansion joints ½ inch wide shall be constructed the full length of the pavement, on each side of the street next to the curb. The joints shall extend the entire depth of the pavement and be filled with Dolarway bitumen and coarse sand or grit. Care shall be taken to fill these joints flush with the surface of the pavement, and before the wearing surface is applied.

Transverse expansion joints may be omitted, unless otherwise directed by the engineer in charge of the work.

13. Not less than 10 days after the concrete has been laid as above specified, and is thoroughly set and perfectly dry, the surface shall be brushed vigorously with a wire broom to remove all loose or insecure particles, and immediately before applying the bitumen it shall be swept with house brooms or flushed with water until clean. After it is perfectly clean and dry there shall be spread over the entire surface a layer of Dolarway bitumen, using not less than one-third nor more than one-half of a gallon to the square yard, said bitumen to be applied at a temperature of not less than 200 degrees Fahrenheit nor more than 250 degrees Fahrenheit.

Immediately following the spreading of the bitumen there shall be spread over the entire surface a uniform layer of dry, clean, sharp sand, or fine washed gravel, or screenings, using not less than one (1) cubic yard to one hundred (100) square yards of surface. No bitumen shall be applied when the temperature is below 40 degrees Fahrenheit, and the sand or screenings shall be applied while the bitumen is sufficiently soft to permit of their becoming thoroughly imbedded in it. After the sand or screenings have been spread, the street shall be closed to travel for a period of not less than two (2) hours, after which time the street may be opened to travel.

Note.—The thickness of the concrete foundation is not specified in the above, nor are the proportions of the materials composing it, as local conditions and requirements must determine these points in each individual instance. The Dolarway Company, however, recommends that the concrete base be composed of a mixture not leaner than 1:2:4 and that its thickness be not less than 5 inches.

APPENDIX I.

SPECIFICATIONS FOR LAYING HASSAMITE.

1. The sub-grade shall be of the same cross section as the finished surface, but of less elevation to the extent of the proposed pavement.

2. In places where fill is required, it may be made with any suitable material excavated from the improvement.

All filling must be made in uniform layers not over 6 inches in depth and each layer shall be thoroughly rolled or tamped as may be required to insure a solid bed.

No material shall be placed in a filled embankment except that which is suitable, whether taken from excavation in the road or elsewhere.

3. The roadbed shall be brought to a solid sub-grade of exact cross section, by rolling or tamping as may be required, and any material which does not produce a firm foundation shall not be permitted in foundation. Any such shall be removed and replaced by material approved by the engineer.

Any extra work to be paid for at cost, plus 10 per cent.

Requirements of Materials.

4. All cement used on this work must fulfill the following requirements. [Standard Specifications of American Society for Testing Materials.]

5. Sand.—The sand for the foundation shall be clean, sharp, and free from clay, loam or organic matter. The sand for the wearing surface shall be of such quality as the contractor may determine.

6. The foundation may be of stone, slag or screened gravel.

7. All water necessary for the construction of the pavement shall be furnished free of cost to the contractor by the city.

Hassam Concrete Foundation.

8. Upon the sub-grade prepared in accordance with the specifications for grading, broken stone shall be spread so that after rolling or compressing, it shall have a uniform thickness of ...... inches.

9. After the stone has been thoroughly compacted and firmly embedded and the voids reduced to a minimum, it shall be grouted with a grout of Portland cement and sand, consisting of two parts sand and one or more parts Portland cement, said grout to be mixed in a Hassam Grout Mixer to insure the accurate blending of the ingredients.

This grout shall be poured upon the foundation until all the voids are filled and the grout flushes to the surface—the stone to be lightly rolled or compressed during the process of grouting, leaving uniform surface.

10. No concrete shall be laid when the temperature at any time day or night falls below 26 degrees F.

Wearing Surface.

11. The surface of the concrete so produced shall be covered with two layers of bituminous composition, known as Hassamite, in one or more substantially equal coats of ¼ gallon each per square yard. This composition shall be applied, when heated, to a temperature of not less than ...... degrees F. and not more than 300 degrees F. Immediately after being applied the first course of composition is to be drifted with screened pea stone, suitable sand or gravel, and rolled with a light steam roller; the second course to be drifted with pea stone, suitable sand or gravel, thoroughly rolled, sufficient sand being added to absorb any surplus composition.

APPENDIX J.

GENERAL SPECIFICATIONS FOR VIBROLITHIC PA MENT.

Sub-Grading.

Excavate, grade, prepare and roll street area to unif(grade, which shall be six inches below the finish grade l

Concrete.

Concrete shall be composed of Portland cement one p and five and one-half parts aggregate; clean silicious sand ; pebble, or crushed hard stone, no stone being greater than t inches in diameter; portion subject to suspension in wa for more than one minute shall not exceed 4 per cent, shall more than 42 per cent, nor less than 33 per cent, p ¼-inch screen.

Mixing.

Concrete shall be mixed in a batch mixer of approved t; with capacity of not less than one bag batch.

Conveying of Concrete.

Concrete shall be conveyed from mixer to street in si manner as not to segregate or in any way unbalance homogeneous mix obtained.

Contraction.

Provision for contraction shall be made by placing uj sub-grade at desired location, thin wooden planes ½x3 inch set on edge in such manner they will occupy bottom one-h concrete cross-section.

Spreading.

All concrete deposited in the street shall be immediat(spread and leveled off with rakes to such grade that af receiving subsequent surfacing stone and vibration the pavi shall have the greatest possible density and shall be of thickness of six inches.

Surface Stone.

Immediately upon spreading, leveling and raking of cc crete there shall be spread upon the surface a coating of si facing stone of trap rock, granite, or their abrasive equ graded through one-inch and retained on ⅝-inch screen. Tł coat shall be of such thickness as will insure a complete surfacing and shall be thoroughly wetted immediately before spreading.

Binding and Solidifying.

Surfacing stone shall be forced into surface of concrete and made a part thereof, and whole mass shall be solidified by the application of vibrations in combination with pressure in such manner as to leave the street uniformly dense and of even texture to even grade.

Method.

Any method may be used in the application of vibrations and pressure. Preferably there shall be placed upon the surface of the spreaded concrete a series of platforms sufficiently flexible to adapt themselves to curvature of street. Immediately upon placing the platform there shall be delivered thereto a rapid succession of small forces, preferably by rolling a vibrator over and along or across the platforms until their bottom edges have been brought to finished grade line.

Protection.

All finished pavement shall be immediately protected from cold or direct rays of the sun.

Initial Protection Coat.

For the purpose of excluding the air and preventing the escape of original moisture contained in the concrete during the period of hydration and as a protection from the abrasion of first traffic, there shall be placed upon the vibrated surface a ¼-inch bituminous coating, composed of vibrator or its equal, and hard stone passing ⅜-inch retained on ⅛-inch screen, upon which shall be placed a sand grit coarse and brought to a smooth surface.

Street Closed.

All finished pavement shall be kept free from traffic for at least ten days after concrete has been vibrated.

Inspection.

Material, construction, finished paving, etc., shall at any time be subject to tests, inspection, supervision and approval of the city engineer or his representative, and in all matters not herein specifically stated, the judgment and decision of the city engineer shall be final.

Patents.

All fees for any patent invention, article agreement, or other apparatus that may be used upon or be in any way connected with the construction, erection or maintenance of the work, or any part thereof, embraced in the contract or these

specifications, shall be included in the price stipulated i
contract for said work, and the contractor or contractors
protect and hold harmless the city against any and a
mands for such fees or claims.

Vibrolithic specifications are copyrighted and pave
is laid under protection of process patent, intention of v
is to maintain and warrant high standard in constructior

Permit to Bid.

Permit to bid and right to lay Vibrolithic can be obt
by reliable and equipped contractors, by applications to
Stubbs, Dallas, Texas.

Guarantee.

The contractor shall furnish a satisfactory surety
guaranteeing the maintenance of the pavement during
period of .... years from and after the da
completion of the same. The maintenance, however, shal
include any damage to the pavement or to the found
thereof, or to any of the other items of work embrace
the contract, which may be incurred by action beyonc
control of the contractor.

Note: Monolithic Street, Curb and Gutter.—Vibro
street paving makes practical the construction of street,
and gutter in one piece. The object and distinct benefit
do away with the objectionable joint between pavement
gutter, as found in all other systems of street paving. V
draining off the crown of the street finds its way through
joint into the foundation, causing curb and gutter to s
out of alignment and grade.

Where all curbs, or curb and gutter are to be constr
new the paving slab extends from back line of curb on
sides of street, with depression over curb and gutter
depth of desired finish. Curbing forms are immediately
and concrete deposited so closely in connection with
ment as to insure bond between concretes. Usual curb fi
ing coats extends out over gutter with grooved joint ¼
deep at line between street and gutter. Curb and gutter
finished and jointed in workmanlike manner.

APPENDIX K.

TYPICAL SPECIFICATIONS FOR REINFORCED CONCRETE BRIDGE AND CULVERT CONSTRUCTION.*

Plans and Drawings.

All concrete masonry shall be built to conform with the lines and dimensions shown on the plans and drawings furnished or approved by the engineer in charge, and which are hereby made a part of these specifications. In cases of discrepancies between figured dimensions and scale, the figured dimensions are to govern.

Concrete.

The concrete shall be of the character and mixed in the proportion indicated on the plans, or as may be indicated in writing by the engineer in charge, or as hereinafter specified. All concrete shall be prepared and placed in strict accordance with the following specifications and plans, and the instructions of the engineer under them.

Cement.

The cement shall be of some standard brand of Portland cement, satisfactory to the engineer in charge. No cement shall be used which, when tested, fails to conform with the United States Government specifications for Portland cement, as contained in Circular 33 of the Bureau of Standards. Cement shall be delivered in sacks of 94 pounds net weight, and each sack shall be considered as having a volume of 1 cubic foot. Cement which contains lumps or has been damaged in any way by exposure to the weather or by other cause shall be rejected.

Sand.

The sand shall consist of dry, clean, sharp quartz grains, and shall not contain more than 5 per cent of clay, loam, or other foreign materials. The grains shall be well graded and of such size that all will pass a ¼-inch mesh screen, and not more than 20 per cent will pass a No. 50 sieve.

Coarse Aggregate.

The coarse aggregate may consist of either broken stone or gravel. Stone shall be sound, hard, and tough, and broken to the sizes hereinafter specified, and when used shall be free from foreign material. No weathered or disintegrated ma-

*Prepared by Charles H. Moorefield, Highway Engineer, Office of Public Roads, Washington, D. C., and published in Bulletin No. 45 of that office.

terial shall be used. Gravel shall be composed of hard, sound, durable particles of stone, thoroughly clean and well graded in size between the limits specified below.

Classes A, B, and C.—Unless otherwise specially provided, there shall be three classes of concrete, known as class A, class B, and class C.

Class A concrete shall consist (by volume) of 1 part of cement, 2 parts of sand, 4 parts of coarse aggregate, and water. All of the coarse aggregate shall be retained on a ¼-inch mesh screen and shall pass a 1-inch mesh screen. Not more than 75 per cent shall be retained on a ½-inch mesh screen, and not more than 75 per cent shall pass such a screen.

Class B concrete shall consist (by volume) of 1 part of cement, 2½ parts of sand, 5 parts of coarse aggregate, and water. All of the coarse aggregate shall be retained on a ¼-inch mesh screen and shall pass a 1½-inch mesh screen. Not more than 75 per cent shall be retained on a ¾-inch mesh screen, and not more than 75 per cent shall pass such a screen.

Class C concrete shall consist (by volume) of 1 part of cement, 3 parts of sand, 6 parts of coarse aggregate, and water. All of the coarse aggregate shall be retained on a ¼-inch mesh screen, and shall pass a 2½-inch mesh screen. Not more than 75 per cent shall be retained on a 1¼-inch mesh screen, and not more than 75 per cent shall pass such a screen.

Mixing.

The cement and sand shall first be thoroughly mixed dry in the proportions specified, on a proper mixing platform. Sufficient clean water shall then be admixed to produce a pasty mortar. To the mortar thus prepared shall be added the proper proportion of coarse aggregate previously drenched with water, and the whole shall be mixed until every particle of the coarse aggregate is thoroughly coated with mortar. Instead of the above method, a mechanical mixer of approved type may be employed.

Size of Batch.

Concrete shall be mixed in batches of such size that the entire batch may be placed in the forms by the force employed within 45 minutes from the time that the first water is applied. No concrete is to be prepared from mortar which has taken an initial set and would require retempering.

Placing.

All concrete shall be carefully deposited in place and never allowed to fall from a height greater than five feet. Concrete shall never be deposited in running water, and when deposited in still water it shall be carefully lowered into place by means of a chute or by some other approved method.

As fast as concrete is put into place, it shall be thoroughly tamped in layers not more than six inches thick, and the portion next to the forms shall be troweled by using a spade or by other means to bring the mortar into thorough contact with the forms.

Concrete shall not be deposited when the temperature of any of the materials composing it is below 35° F., and if during the progress of the work freezing temperature threatens or is predicted by the United States Weather Bureau, proper precautions shall be taken to protect from freezing all concrete laid within the four preceding days.

Forms.

Forms shall be so constructed as to continue rigidly in place during and after depositing and tamping the concrete. If during the placing of the concrete the forms show signs of bulging or sagging at any point, that portion of the concrete causing the distortion shall be immediately removed and the forms properly supported before continuing the work. The amount of concrete to be removed shall be determined by the engineer, and the contractor shall receive no extra compensation on account of the extra work thus occasioned. Forms for exposed surfaces shall be constructed of dressed lumber.

All forms shall be left in place not less than 36 hours, and all supporting forms not less than 10 days after the concrete has been deposited. These periods may be increased at the discretion of the engineer in charge.

It is understood that all prices for concrete masonry shall include furnishing all materials and properly constructing all necessary forms.

Joints.

When the work of laying concrete is to be interrupted for a period greater than 1 hour and there are no reinforcing rods projecting, provision for a joint shall be made in the following manner: Square timbers 8 inches by 8 inches, or some other suitable size approved by the engineer, shall be bedded in the concrete throughout the length of the course for one-half their thickness and allowed to remain until the concrete has taken its initial set. When the work of laying concrete is resumed, the timbers shall be removed and the surface thoroughly wet. No joints will be permitted in reinforced concrete beams, and in floor slabs the joints shall be vertical and parallel to the main reinforcing bars.

Finish.

Forms covering surfaces of the concrete masonry which are to be exposed shall be removed immediately after the expiration of the period of time necessary for such forms remain in place, as fixed by the engineer, and all crevi which may appear shall be filled with 1:2 cement mor These surfaces shall then be finished with 1:2 cement mor and a wooden float, so as to present a smooth, neat pearance.

Reinforced Concrete.

All reinforced arches, beams, floors, parapets, guard ra and all concrete masonry measuring less than 9 inches thickness shall be made of class A concrete, unless ot wise specified on the drawings or directed by the engin in writing.

Abutments and Wing Walls.

Unless otherwise specified on the drawings or in w ing by the engineer, class B concrete shall be used for abutments and wing walls, the thickness of which is not l than 9 inches.

Footings and Cut-Off Walls.

Class C concrete shall be used for all footings and cut walls, unless otherwise specified on the plans or directed writing by the engineer.

Steel for Reinforced Concrete.

Unless otherwise specified on the drawings, all reinf ing steel shall consist of bars which have been deformed some approved manner. No plain bars will be permit except as shown on the drawings or directed in writing the engineer.

The steel bars shall have the net sectional area and placed in the exact positions indicated on the drawings.

Unless otherwise specified on the drawings or in writ by the engineer, all reinforcing bars shall be of medium st having an elastic limit of not less than 35,000 pounds square inch, and shall be sufficiently malleable to withst bending cold with a radius equal to twice the diameter thickness of the bar through 180° without fracture.

When placed in the concrete, the reinforcing steel sh be free from grease, dirt, and rust, and it shall be the d of the contractor to provide means for properly cleaning steel.

Thorough contact of the concrete with every portion the surface of the steel shall be obtained.

Splicing Reinforcing Bars.

Unless otherwise specified on the drawings or in writ by the engineer, necessary splices in reinforcing bars sh be effected by overlapping the ends of the bars a dista equal to forty times their thickness or diameter.

APPENDIX L.

SPECIFICATIONS OF AMERICAN CONCRETE INSTITUTE.

SIDEWALKS.

Materials.

1. Cement.—The cement shall meet the requirements of the Standard Specifications for Portland Cement of the American Society for Testing Materials and adopted by this Association. Standard No. 1.

2. Fine Aggregate.—Fine aggregate shall consist of sand, crushed stone or gravel screenings, graded from fine to coarse and passing, when dry, a screen having ¼-inch diameter holes; shall be preferably of silicious material, clean, coarse, free from dust, soft particles, loam, vegetable or other deleterious matter, and not more than 3 per cent shall pass a sieve having 100 meshes per linear inch. Fine aggregate shall be of such quality that mortar composed of one part Portland cement and 3 parts fine aggregate by weight, when made into briquettes will show a tensile strength at least equal to the strength of 1:3 mortar of the same consistency made with the same cement and Standard Ottawa sand. In no case shall fine aggregate containing frost or lumps of frozen material be used.

3. Coarse Aggregate.—Coarse aggregate shall consist of inert materials such as crushed stone or gravel, graded in size, retained on a screen having ¼-inch diameter holes; shall be clean, hard and durable; free from dust, vegetable or other deleterious matter, and shall contain no soft, flat or elongated particles. In no case shall coarse aggregate containing frost or lumps of frozen material be used. The maximum size of coarse aggregate shall be such as to pass a 1¼-inch ring.

4. Natural Mixed Aggregates.—Natural mixed aggregates shall not be used as they come from the deposit, but shall be screened and remixed to agree with the proportions specified.

5. Sub-base.—Only clean, hard, suitable material, not exceeding 4 inches in the largest dimensions shall be used.

6. Water.—Water shall be clean, free from oil, acid, alkali or vegetable matter.

7. Coloring.—If artificial coloring material is required, only mineral colors shall be used.

8. Reinforcing Metal.—The reinforcing metal shall meet

the requirements of the Standard Specifications for Steel Reinforcement adopted March 16, 1910, by the American Railway Engineering Association.

Sub-Grade.

9. Slope.—The sub-grade shall have a slope toward the curb of not less than ½ inch per foot.

10. Depth.*—(a) The sub-grade shall not be less than 11 inches below the finished surface of the walk.

(b) The sub-grade shall not be less than 5 inches below the finished surface of the walk.

11. Preparation.—All soft and spongy places shall be removed and all depressions filled with suitable material which shall be thoroughly compacted in layers not exceeding 6 inches in thickness.

12. Deep Fills.—When a fill exceeding 1 foot in thickness is required to bring the work to grade, it shall be made in a manner satisfactory to the engineer. The top of all fills shall extend beyond the walk on each side at least 1 foot, and the sides shall have a slope not greater than 1 to 1½.

13. Drainage.—When required, a suitable drainage system shall be installed and connected with sewers or other drains indicated by the engineer.

Sub-Base.*

14. Width.—Thickness.—On the sub-grade shall be spread a suitable material as hereinbefore stated which shall be thoroughly rolled or tamped to a surface at least 5 inches below the finished grade of the walk. On the fills, the sub-base shall extend the full width of the fill and the sides shall have the same slope as the sides of the fill.

15. Wetting.—While compacting the sub-base, the material shall be kept thoroughly wet and shall be in that condition when the concrete is deposited.

Forms.

16. Materials.—Forms shall be free from warp and of sufficient strength to resist springing out of shape.

17. Setting.—The forms shall be well staked or otherwise held to the established lines and grades and their upper edges shall conform to the established grade of the walk.

18. Treatment.—All wood forms shall be thoroughly wetted and metal forms oiled before depositing any material against them. All mortar and dirt shall be removed from forms that have been previously used.

Construction.

19. Size of Slabs.—The slabs or independently divided

*Note.—When a sub-base is required, eliminate Paragraph 10 (b). When a sub-base is not required, eliminate Paragraphs 5 and 10 (a). Unless Paragraph 10 (a) is eliminated, 10 (b) is void.

blocks when not reinforced shall have an area of not more than 36 square feet and shall not have any dimension greater than 6 feet. Larger slabs shall be reinforced as hereinafter specified.

20. Thickness of Walk.—The thickness of the walk should not be less than 5 inches for residence districts, and not less than 6 inches for business districts.

21. Width and Location of Joints.—A ½-inch expansion joint shall be provided at least once in every 50 feet.

22. Joint Filling.—The expansion joint filler shall be a suitable elastic waterproof compound that will not become soft and run out in hot weather, nor hard and brittle and chip out in cold weather.

23. Protection of Edges.—Unless protected by metal, the upper edges of the concrete shall be rounded to a radius of ½ inch.

Measuring and Mixing.

24. Measuring.—The method of measuring the materials for the concrete, including water, shall be one which will insure separate uniform proportions at all times. A sack of Portland cement (94 lbs. net) shall be considered 1 cubic foot.

25. Machine Mixing.—When the conditions will permit, a machine mixer of the type that insures the uniform proportioning of the materials throughout the mass, shall be used. The ingredients of the concrete or mortar shall be mixed to the desired consistency and the mixing shall continue until the cement is uniformly distributed and the mass is uniform in color and homogeneous.

26. Hand Mixing.—When it is necessary to mix by hand, the materials shall be mixed dry on a watertight platform until the mixture is of uniform color, the required amount of water added and the mixing continued until the mass is uniform in color and homogeneous.

27. Retempering, that is, remixing mortar or concrete that has partially hardened with additional water, will not be permitted.

TWO-COURSE WALKS.

Base.

28. Proportions.—The concrete shall be mixed in the proportion by volume of 1 sack Portland cement, 2½ cubic feet fine aggregate and 5 cubic feet coarse aggregate.

29. Consistency.—The materials shall be mixed wet enough to produce a concrete of a consistency that will flush readily under slight tamping, but which can be handled without causing a separation of the coarse aggregate from the mortar.

30. Placing.—After mixing, the concrete shall be handled

rapidly and the successive batches deposited in a continuou operation completing individual sections. Under no circum stances shall concrete be used that has partially hardened The forms shall be filled and the concrete struck off an tamped to a surface the thickness of the wearing cours below the established grade of the walk. After the concret has been thoroughly tamped against the cross forms, the shall be removed and the material for the adjoining slab de posited so as to preserve the joint. Workmen shall not b permitted to walk on the freshly laid concrete, and if sand o dust collects of the base it shall be carefully removed befor the wearing course is applied.

31. Reinforcing.—Slabs having an area of more than 3 square feet, or having any dimension greater than 6 feet shall be reinforced with wire fabric or with plain or deforme bars. The cross sectional area of metal shall amount to a least 0.041 square inches per lineal foot. The reinforcin metal shall be placed upon and slightly pressed into the con crete base immediately after the base is placed. Reinforcin metal shall not cross joints and shall be lapped sufficientl to develop the strength of the metal.

Wearing Course.

32. Proportions.—The mortar shall be mixed in the man ner hereinbefore specified in the proportion of 1 sack Port land cement and not more than 2 cubic feet of fine aggregate

33. Consistency.—The mortar shall be of a consistenc that will not require tamping, but which can be easily sprea into position.

34. Thickness.—The wearing course of walk in residenc districts shall have a minimum thickness of ¾ of an inch and in business districts a minimum thickness of 1 inch.

35. Placing.—The wearing course shall be placed im mediately after mixing and in no case shall more than 5 minutes clause between the time the concrete for the bas is mixed and the time the wearing course is placed.

36. Finishing.—After the wearing course has bee brought to the established grade, it shall be worked with a wood float in a manner that will thoroughly compact it When required, the surface shall be troweled smooth, bu excessive working with a steel trowel should be avoided The slab markings shall be made in the wearing cours directly over the joints in the base with a tool which wil completely separate the wearing course of adjacent slabs If excessive moisture occurs on the surface, it must be take up with a rag or mop, and in no case shall dry cement or a mixture of dry cement and sand be used to absorb this moist ure or to hasten the hardening. Unless protected by metal the surface edges of all slabs shall be rounded to a radius o about ½ inch.

37. Coloring.—If artificial coloring is used, it must be incorporated with the entire wearing course, and shall be mixed dry with the cement and aggregate until the mixture is of uniform color. In no case shall the amount of coloring used exceed 5 per cent of the weight of the cement.

ONE-COURSE WALK.

The general requirements of the specifications covering two-course work will apply to one-course work with the following exceptions:

38. Proportions.—The concrete shall be mixed in the proportion of 1 sack Portland cement to not more than 2 cubic feet of fine aggregate, and 3 cubic feet of coarse aggregate passing a 1-inch ring.

39. Placing and Finishing.—The form shall be filled, the concrete struck off and the coarse particles forced back from the surface, and the work finished in the usual way.

40. Reinforcing.—When a single course walk is to be reinforced, the metal shall be placed at the middle of the section. The minimum amount of metal shall be as specified in paragraph 31.

Protection.

41. Treatment.—As soon as the concrete has hardened sufficiently to prevent being pitted, the surface of the walk shall be sprinkled with clean water and kept wet for at least 4 days. The walk shall not be opened to traffic until the engineer so directs.

42. Temperature Below 35° F.—If at any time during the progress of the work the temperature is, or in the opinion of the engineer will within 24 hours drop to 35 degrees Fahrenheit, the water and aggregate shall be heated and precautions taken to protect the work from freezing for at least 5 days. In no case shall concrete be deposited upon a frozen sub-grade or sub-base.

APPENDIX M.

SPECIFICATIONS OF AMERICAN CONCRETE INSTITUTI

CURB AND GUTTER.

Materials.

1. Cement.—The cement shall meet the requirements (the Standard Specifications for Portland Cement of the Amer can Society for Testing Materials and adopted by this A sociation. (Standard No. 1.)

2. Fine Aggregate.—Fine aggregate shall consist (sand, crushed stone or gravel screenings, graded from fin to coarse, and passing, when dry, a screen having ¼-inc diameter holes; shall be preferably of silicious materia clean, coarse, free from dust, soft particles, loam, vegetabl or other deleterious matter, and not more than 3 per cer shall pass a sieve having 100 meshes per linear inch. Fin aggregate shall be of such quality that mortar composed of part Portland cement and 3 parts fine aggregate by weigh when made into briquettes will show a tensile strength a least equal to the strength of 1:3 mortar of the same coi sistency made with the same cement and Standard Ottaw sand. In no case shall fine aggregate containing frost c lumps of frozen material be used.

3. Coarse Aggregate.—Coarse aggregate shall consist c inert ma rials such as crushed stone or gravel graded i size, ret ied on a screen having ¼-inch diameter holes shall be clean, hard and durable, free from dust, vegetabl or other leleterious matter, and shall contain no soft, fla or elongated particles. In no case shall coarse aggregat containing frost or lumps of frozen material be used. Th maximum size of coarse aggregate shall be such as to pas a 1¼-inch ring.

4. Natural Mixed Aggregates.—Natural mixed aggre gates shall not be used as they come from the deposit, bu shall be screened and remixed to agree with the proportion specified.

5. Sub-Base.—Only clean, hard, suitable materials, no exceeding 4 inches in the largest dimension shall be used.

6. Water.—Water shall be clean, free from oil, acid alkali or vegetable matter.

7. Coloring.—If artificial coloring material is required only mineral colors shall be used.

Sub-Grade.

8. Depth Below Grade.—(a) Concrete Curb—When a sub-base is required, the sub-grade shall not be less than 30 inches below the established grade of the curb.

(b) Concrete Curb and Gutter.—When a sub-base is required, the sub-grade shall not be less than 11 inches below the established grade of the gutter.

9. Preparation.—All soft and spongy places shall be removed and all depressions filled with suitable material, which shall be thoroughly compacted in layers not exceeding 6 inches in thickness.

10. Deep Fills.—When a fill exceeding 1 foot in thickness is required to bring the work to grade, it shall be made in a manner satisfactory to the engineer.

11. Drainage.—When required, a suitable drainage system shall be installed and connected with sewers or other drains indicated by the engineer.

Sub-Base.

12. Thickness. (a) Concrete Curb.—On the sub-grade shall be spread a material as hereinbefore specified, which shall be thoroughly rolled or tamped to a surface at least 24 inches below the established grade of the curb.

(b) Concrete Curb and Gutter.—On the sub-grade shall be spread a material as hereinbefore specified, which shall be thoroughly rolled or tamped to a surface at least 6 inches below the established grade of the gutter.

13. Wetting.—While compacting the sub-base, the material shall be kept thoroughly wet and shall be in that condition when the concrete is deposited.

Forms.

14. Materials.—Forms shall be free from warp, and of sufficient strength to resist springing out of shape.

15. Setting.—The forms shall be well staked or otherwise held to the established lines and grades, and their upper edges shall conform to the established grade of the curb or curb and gutter.

16. Treatment.—All wood forms shall be thoroughly wetted and metal forms oiled before depositing any material against them. All mortar and dirt shall be removed from forms that have been previously used.

Construction.

17. Dimension of Curb.—The section of the curb shall conform with that shown in Fig. 1. The thickness at the base shall not be less than 12 inches, and at the top not more than 6 inches, with a batter on the street side of 1 to 4.

18.—Dimensions of Curb and Gutter.—The sections of the combination curb and gutter shall conform with tha shown in Fig. 2. The depth of the back of the curb shal not be less than 12 inches and the depth of the face not les than 6 inches. The breadth of the gutter shall not be les than 16 inches nor more than 24 inches.

19. Size of Sections.—The curb and gutter shall be d: vided into sections not less than 5 nor more than 8 feet lon; by some method which will insure the complete separatio of the sections.

20. Section at Street Corners.—The construction of th combination curb and gutter at street corners shall conforr with that shown in Figure 3. The radius of the curb shal not be less than 6 feet.

21. Width and Location of Joints.—A ½-inch expansio joint shall be provided at least once in every 150 feet.

22. Joint Filler.—The expansion joint filler shall be suitable, elastic, waterproof compound that will not becom soft and run out in hot weather, nor hard and brittle and chi out in cold weather.

23. Protection of Edges.—Unless protected by metal, th upper edges of the concrete shall be rounded to a radius c ½ inch.

Measuring and Mixing.

24. Measuring.—The method of measuring the material for the concrete, including water, shall be one which will i sure separate uniform proportions at all times. A sack c Portland cement (94 pounds net) shall be considered 1 cubi foot.

25. Machine Mixing.—When the conditions will permi a machine mixer of a type which insures the uniform pr portioning of the materials throughout the mass, shall t used. The ingredients of the concrete or mortar shall b mixed to the desired consistency and the mixing shall co tinue until the cement is uniformly distributed and the ma is uniform in color and homogeneous.

26. Hand Mixing.—When it is necessary to mix by han the materials shall be mixed dry on a watertight platfor until the mixture is of uniform color and the required amou of water added, and the mixing continued until the mass uniform in color and homogeneous.

27. Retempering, that is remixing mortar or concre that has partially hardened, with additional water, will n be permitted.

TWO-COURSE CURB AND CURB AND GUTTER.

Base.

28. Proportions.—The concrete shall be mixed in th proportion of 1 sack Portland cement, 2½ cubic feet fine aggr gate, and 5 cubic feet coarse aggregate.

29. Consistency.—The materials shall be mixed wet enough to produce a concrete of a consistency that will flush readily under slight tamping, but which can be handled without causing a separation of the coarse aggregate from the mortar.

30. Placing.—After mixing, the concrete shall be handled rapidly and the successive batches deposited in continuous operation completing individual sections. Under no circumstances shall concrete be used that has partially hardened. The gutter forms shall be filled and the concrete struck off and tamped to a surface the thickness of the wearing course below the established grade of the gutter. The concrete for the curb shall be placed and tamped so as to permit of the application of the required wearing course to the face and top so as to bring the work to the established line and grade of the curb. The work shall be executed in a manner which will insure perfect joints between abutting sections. Workmen shall not be permitted to walk on freshly laid concrete, and if sand or dust collects on the base, it shall be carefully removed before the wearing course is applied.

Wearing Course.

31. Proportions.—The mortar shall be mixed in the manner hereinbefore specified in the proportion of 1 sack Portland cement and not more than 2 cubic feet of the fine aggregate.

32. Consistency.—The mortar shall be of a consistency that will not require tamping, but which can be easily spread into position.

33. Thickness.—The wearing course of the gutter and top and face of the curb shall have a minimum thickness of ¾ of an inch.

34. Placing.—The wearing course shall be placed immediately after mixing, and in no case shall more than 50 minutes elapse between the time the concrete for the base is mixed and the time the wearing course is placed.

35. Finishing.—After the wearing course has been brought to the established line and grade, it shall be worked with a wood float in a manner which will thoroughly compact it. When required, the surface shall be troweled smooth, but excessive working with a steel trowel shall be avoided. The section markings shall be made in the wearing courses directly over the joints in the base with a tool which will completely separate the wearing courses of adjacent sections. If excessive moisture occurs on the surface, it must be taken up with a rag or mop, and in no case shall dry cement or a mixture of dry cement and sand be used to absorb this moisture or to hasten the hardening. The edge of the curb on the street side and the intersection of the curb and gutter shall be rounded to a radius of about 1½ inches. All other edges

shall be rounded to a radius of ⅜ inch unless protected by metal.

36. Coloring.—If artificial coloring is used, it must be incorporated with the entire wearing course and shall be mixed dry with the cement and aggregate until the mixture is of uniform color. In no case shall the amount of coloring used exceed 5 per cent of the weight of the cement.

One-Course Curb and One-Course Curb and Gutter.

The general requirements of the specifications covering two-course work will apply to one-course work, with the following exceptions:

37. Proportions.—The concrete shall be mixed in the proportion of 1 sack Portland cement and not more than 2 cubic feet of fine aggregate, and 3 cubic feet of coarse aggregate passing a 1-inch ring.

38. Placing and Finishing.—The forms shall be filled, the concrete struck off and the coarse particles forced back from the surface, and the work finished in usual way.

Protection.

39. Treatment.—As soon as the concrete has hardened sufficiently to prevent being pitted, it shall be sprinkled with clean water and kept wet for at least 4 days. The work shall not be opened to traffic until the engineer so directs.

40. Temperature below 35° F.—If at any time during the progress of the work, the temperature is, or in the opinion of the engineer will within 24 hours drop to 35 degrees Fahrenheit, the water and aggregates shall be heated and precautions taken to protect the work from freezing for at least 5 days. In no case shall concrete be deposited upon a frozen sub-grade or sub-base.

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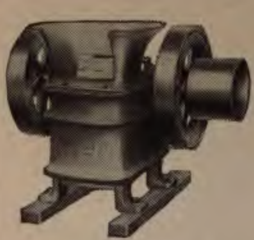

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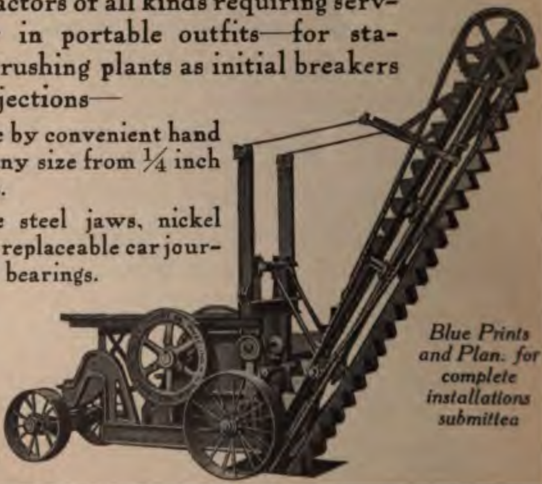

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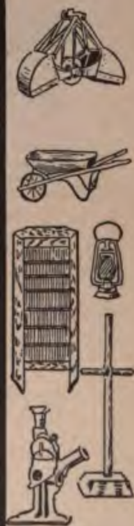

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THE ATLAS MIXEF

Represents the best established practice in concrete mixer constructi

Made with Batch Hopper or Side Loader

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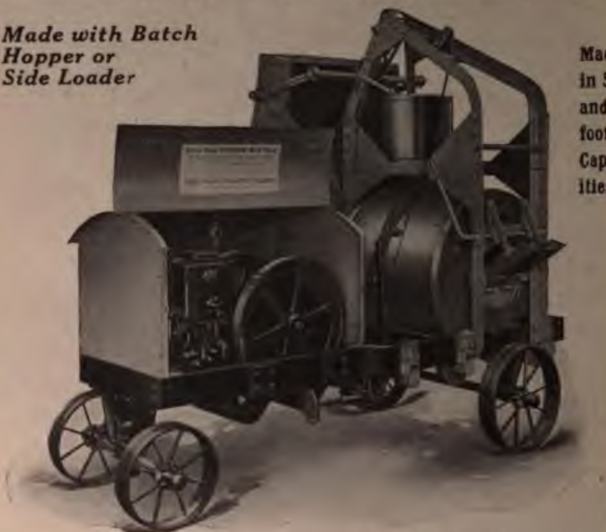

Write for Literature on Road Building Machinery

Made for the contract who intends to stay in bu iness. An ATLAS on tl job will mean more prol for you.

The ATLAS Mixer Book is yours for the asking.

ATLAS ENGINEERING CO. General Offices and Worl
MILWAUKEE, WIS., U. S.

BRAGSTAD CONTINUOUS BATCH MIXER

Presto!

You change it to mix in *batches* or continuously — just as you want it.

Whether the concrete paving contract calls for batch or continuous mixing, you need no other mixer than your

Bragstad Concrete Mixer

It does both. Another great advantage the Bragstad has over many others is its low down hopper. This does away with runways and labor of lifting materials.

Accurate proportioning is assured by its measurements, regulated by buckets, slides and hopper. The feed is always in control. The material is mixed dry in one chamber and wetted in another.

The Bragstad is extremely simple in operation and has no complicated parts to get out of order. Every part tried out and tested until it is known to be right before it leaves the factory. Let us acquaint you with the merits and quality of our Mixers, Tampers and Block Machines. Our catalog shows them all. Send for a copy. The very best machines for the money. The Block Machine makes "The Best Cement Block in the World."

Bragstad Concrete Machinery Co.

CANTON, SOUTH DAKOTA

A Sturdy Lightweight Mixer

Built to Stand Hard Work and Long Hauls over Rough Roads

BOSS "*Highway*" Special

With LOW LOADING Measuring Hopper

28″ Rear—20″ Front Wheels—4″ Tires

Runs in standard wagon track.

POWER LOADER OR LOW BARROW HOPPER IF DESIRED

A Larger Mixer
at a
Low Price

STEEL KING

10 FT.

Batch Mixer

Built of Steel

Lightest Big Capacity Mixer Built.

Made in rear discharge, swinging chute traction.

Write for Catalog.

The American Cement Machine Co., Inc.
1008 Johnson St., Keokuk, Ia.

Street Paving, Delaware, Ohio. C. W. Riddle, Contractor

The Knickerbocker Co.,
Jackson, Mich.

GENTLEMEN:—The concrete turned out by my No. 12 Coltrin, according to a statement by our City Engineer, Mr. Geo. Irwin, was the best ever put in any of the paving that has been done in Delaware. He is perfectly satisfied that the Coltrin will give all the mixtures claimed for it and personally spent half a day testing out the Mixer before allowing its use on the work.

I ran 78 cu. yds. in one day with a crew of nine men—three stone shovelers, two sand shovelers, three wheelers and one man to look after the cement. I concreted one square 30 ft. wide, 405 ft. long and 6 in. thick with seven gallons of gasoline. The Coltrin did splendid work and surprised other contractors who had given me the laugh about Riddle's 'Coffee Mill." I delivered the goods and didn't need an engineer to fire the boiler.

Enclosed you will find photo of street paving concrete being mixed by my Coltrin.

Yours truly,
CHAS. W. RIDDLE

The Coltrin Continuous Batch Mixer

Shipped anywhere on five days trial

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The Knickerbocker Company

JACKSON, MICHIGAN

On the National Lincoln Highway

The mixer used to produce the 40,000 cubic yards of concrete in the Essex-Hudson Plank Road, carrying the heavy traffic between Newark and Jersey City, was the

EUREKA SELF MEASURING MIXER

"WHERE GUESS WORK ENDS"

Costs one-half as much to buy, one-third as much to run, one-fifth as much to move.

Foı your own profit and a lot of it, get our catalog No. 46.

Eureka Machine Co.
23 Case Street
Lansing, Mich.

An Ideal Paving Mixer

TRACTION—A mixer that will move forward with its own power as work progresses.

QUALITY MIXING—A mixer that will proportion accurately and mix thoroughly.

QUANTITY MIXING—A mixer that will mix enough concrete and one that is only limited to the amount of material fed into the hoppers.

FEEDING AND DISCHARGING—A mixer with low hoppers and long spouting trough to discharge concrete into place.

that's a Hartwick

the Traction, Paving Mixer with the Double Trough.

CITY OF DETROIT

Detroit, Mich., December 23, 1913.

"The Department of Public Works of the City of Detroit, Sidewalk Department, have been using two of your No. 2½ Hartwick double trough mixers for the past three years, and in my department they have done an enormous amount of concrete work, and I can recommend them to be reliable and fast operating machines." —By J. C. Davis, Supt.

Get our catalog before buying your next paving mixer. It will pay you to investigate the Hartwick.

HALL-HOLMES MFG. CO., 502 Oak St., Jackson, Mich.

Makers of the Famous Grand Continuous Mixers

The "Better Roads" Movement

has greatly increased the demand for the

Ideal "Cincinnatus" Batch Mixer

The "Cincinnatus" Mixer has rightly been called the "Contractor's friend" because of its durability, its convenience of operation and its capacity for work.

There is honest value in every part entering into the construction of this Mixer. It is a serviceable machine and one that can always be depended upon. We can't go into detail about its construction and operation here, but any requests for literature or detailed information will be given prompt and courteous attention.

Ideal Concrete Machinery Company

Monmouth Ave., near Colerain :: CINCINNATI, OHIO

It's Not a Big Mixer **It's Not a Little Mixer**

It's a "Big-an-Litle"

It fits, where the big mixer won't do and where the little mixer falls short of service. There are some concrete paving jobs too small for big mixers on which a mixer like the "Big-an-Litle" is the ideal machine. And for curb and gutter, sidewalk or other municipal concrete jobs it can't be surpassed.

It's just this kind of a mixer that puts dollars into your pockets

That's giving perfect satisfaction for years. That's simple, compact, durable, with a good capacity, and a price that's right.

"Big-an-Litle" Mixers are furnished with or without loaders, just as you please. The loading device can be used for hoisting.

There's big value in a "Big-an-Litle" Mixer. It will easily increase your profits and knock big holes in expense. It's sold under an ***Iron-clad Guarantee*** that is positive protection for you. One price to all.

CATALOGUE ON REQUEST

JAEGER MACHINE COMPANY

217 W. Rich Street **COLUMBUS, OHIO**

On *Capacity* hangs your balance

—your profit or loss

Profits in Concrete Road Paving depend upon the output

of your mixer. The steady grind, the steady flowing stream of concrete. The cost of materials is alike, but mixing costs vary. Bear this in mind before next job is started—make sure only a

Northwestern Cone Batch Mixer

is used. Note the shape and tilt of drum—that aids capacity. Note the wide chilled bearings—that gives long life.

Look These Features Cver

Combined mixing principle of cone and cylindrical shape drum; drop and whirlpool mix; low charging; high discharge; four-point bearing support; all chilled bearings; chain drive; hot riveted and braced truck frame; wide truck wheels; can be turned within its own length; **SPEEDY**—batch a minute; first cost only cost; no expense for up-keep; light, strong, portable.

Remember it's the man who mixes and places concrete most economically that gets the big profits, and the **Northwestern** is the mixer. Ask for Mixer Catalog.

Northwestern Steel & Iron Works

EAU CLAIRE, WISCONSIN

"The Mixers that Make the Money"

LITTLE WONDER "FIVE"

AND

THE WONDER "TEN"

CAPACITIES:—5 and 10 Cu. Ft. per batch—35 to 50 and 60 to 90 Cu. Yds. per day, respectively, *without* SIDE LOADERS. SIDE LOADERS double these outputs.

PROVED SUCCESSES in every field of Concrete engineering, with nation wide endorsement, these mixers present exclusive features in actual money-earning, money-saving points that entitle them to your careful consideration before deciding upon any machine.

Strong, swift, dependable under all conditions. Perfect mix—always visible and easily regulated. Easy operation—quick discharge without clogging—self-cleaning drum—automatic water-measuring tank—rotary pump.

Strongest possible construction, with triple A-Frame Standards—long main shaft and wide bearings. I-Beam Steel Section Frame and Axles—staggered steel wheels—wide tires—standard tread. 2½ and 4½ HP gasoline engines respectively.

For speed and volume on highway and municipal work, and for general utility and adaptability under all conditions—WONDER mixers challenge comparison and ask only the opportunity to prove these claims on your own work, without any obligation to you.

Write for our "MAN TO MAN" proposition

WATERLOO CEMENT MACHINERY CORPORATION

91 Vinton St., WATERLOO, IOWA

NEW YORK PHILADELPHIA CHICAGO KANSAS CITY MONTREAL

AND 100 SERVICE STATION AGENCIES—WRITE FOR NEAREST TO YOU

SEND FOR SMITH—CHICAGO PAVER CATALOG No. 79-P

RECORD OUTPUTS ALL THE TIME WITH SMITH-CHICAGO PAVERS

The output of any paving mixer depends primarily on how fast it can be loaded. No matter how fast the drum mixes, nor how rapidly the concrete is distributed, if the charging end is slow, the output is reduced. The big, wide, centrally located charging skip on the Smith-Chicago Paver does the business and makes possible the enormous output for which these machines are noted. On the one-bag size—the No. 509—this skip is 5 ft. 6 in. wide — enough so that two barrows can be emptied at once. On the two-bag size — the No. 514 — the skip is 8 ft. in width — wide enough for three barrows to be emptied simultaneously.

Check over some of the other features as well—Centrally located power plant. All the weight is equally distributed over the heavy substantial steel truck. Powerful forward and reverse traction mechanism. All levers banked in one place. Large wide wheels that track. Rear wheels attached to steering knuckles on axle. Distributing chutes up to 20 feet in length. These are equipped with tip-ups for intermediate discharge.

*Send for Smith-Chicago Paver Catalog No. **79-P** for further information.*

THE T. L. SMITH COMPANY

3116 Hadley Street **MILWAUKEE, WIS.**

REPRESENTATIVES IN ALL LARGE CITIES

Special Mixers Are Demanded

For both Quality and Economy of Concrete Road Construction

A moving mixing plant is necessary; one which can be charged quickly from ground level; one which distributes the mixed concrete evenly and at any point of the road width; and one which reduces manual labor to the minimum.

The Austin Improved Cube Special Road Mixer is self-propelling and will travel anywhere on a road-grade.

The Austin Improved Cube Special Road Mixer is mechanically charging from ground level.

The Austin Improved Cube Special Road Mixer discharges, places and spreads the concrete mechanically.

One Man directs all the mechanical operations—charging, mixing, placing and moving ahead.

Perfect Mixing is scientific mixing—mixing by incorporation under pressure—which is the mixing principle of **The Austin Improved Cube Mixer.**

Write for Catalogue and Road Mixer Circular No. 20.

Municipal Engineering & Contracting Co.

Railway Exchange Bldg., Chicago

Eastern Office: 30 Church Street, New York

The Mixer that Proves Its Quality by Its Record

How much you must charge up to depreciation and repairs are as important questions in determining the real cost of a mixer as the initial expense.

How much of your labor cost is due to delays directly traceable to the mixer, is another important item to consider when comparing initial cost.

It's the Koehring Quality Mixer that proves its dollar earning quality by its record of continuous service and low cost of maintenance.

Catalogue 119—the most complete mixer catalogue gives details.

KOEHRING MACHINE CO.
MILWAUKEE, WIS.

Claims and Promises
—— or ——
Facts and Guarantees

When you make any investment you do so for the purpose of making money. The dollar invested in anything less valuable than the BEST will cost more than the best later on—because the results are not produced.

Claims and **Promises** do not give results—they fall short at the producing end—they mean nothing to you.

Facts and **Guarantees** make sure the profits—they are productive, they are a certainty. You need not accept mere promises when you buy the **Koehring Mixer.** The statement of thousands of users are **Facts**—the results they obtain are a **Guarantee** to you.

Then there is the Koehring Guarantee that the **results** with a Koehring Mixer will be **greater dollar for dollar** than would be possible in any other mixer. In its strength alone the Koehring is distinctive. And strength is an important item in machinery. But the Koehring goes beyond the mere argument of strength. It **mixes faster and better**, and faster and better are important elements in modern business. **Time** counts on **your** work.

With a Koehring you get guaranteed service—no delays to eat up your profits.

Just write for the New Koehring Catalog No. 119.

KOEHRING MACHINE CO.
MILWAUKEE, WIS.

The "Milwaukee" Street Paver

The most improved paver on the market today. A paver that has demonstrated its efficiency in every conceivable way.

A Few "Milwaukee" Points

Easy one man control.
All levers within the reach of the operator.
Power steering device.
Chain drive.
High and wide traction wheels.
Traction drive forward and reverse.
Differential housed and running in oil.
Distributing boom swinging at an angle of 180° automatically discharges material at any point along boom.

These are features that must be seen to be appreciated. The most compact and a stronger and more durable machine with the greatest efficiency.

Our claims are endorsed by many testimonial letters.

Write us and we will *prove* it.

We also manufacture the Wisconsin Low Charging Mixers and a full line of Milwaukee Standard Mixers.

Ask for Folder "F"

Milwaukee Concrete Mixer Co.

Milwaukee, Wis.

Chain Belt Paver

"The Mixer with the Bulge"

**is positively operated
by one man**

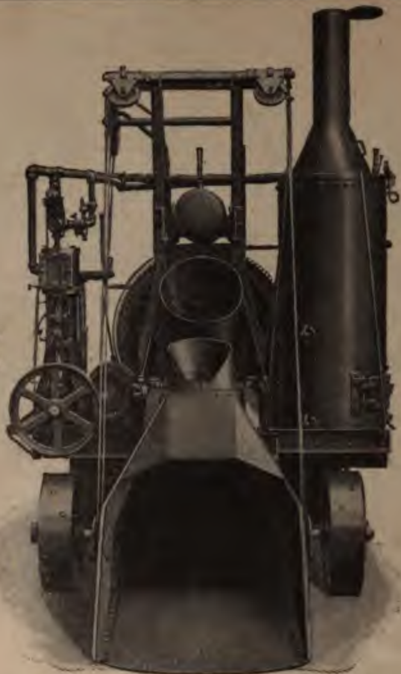
Built in accordance with the specifications submitted by the National Road Builders' Conference held recently in Chicago.

Machine is two-way traction drive, can travel a mile an hour, on its own power. Can easily climb a 10% grade—has more than enough power and is built by a concern who have been manufacturing machinery continuously for twenty-five years.

CHAIN BELT COMPANY

MILWAUKEE, WIS.

"Most Mixing



Least Fixing"

Showing Pivoted End Charging Hopper

Find Out More About It

Little can be said in this small space about the M-C RAIL-TRACK PAVER, but we do say this: "The paver has all the good features of all other pavers—and more."

M-C Rail-Track Paver

is speedy—strong—sturdy—easy to operate—handy—economical. Only one engineer is needed. Unexcelled Distributors for wide or narrow streets and road work. Powerful Differential—Strong Brakes—12 h. p. Gasoline Engine, or 10 h. p. Steam Engine with 12 h. p. Boiler. No need of horses in moving from job to job—no danger. Capacity—11 cu. ft. of mixed concrete per batch, or 16 cu. ft. of unmixed sand, stone and cement.

We know the price will interest you.

Marsh-Capron Mfg. Co. 400 Old Colony Bldg. CHICAGO